Forest Service Southern Region
Changing Land Use Position Paper Project

Literature Review Part I: The drivers of land use change

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1 TOPIC AND APPROACH

1.1 Land use and land cover conceptualized

Prior to delving into the body of land use/land cover literature, a brief discussion of terminology is in order. Usage of terms in this review will follow that described by Turner & Meyer (1994), who note that "the topic of land transformation divides conveniently into two linked components: those of land-use and land-cover change."[1] Land use refers to "the human employment of the land," and includes settlement, cultivation, recreation, and any number of other uses. While land use is a reflection of landowner objectives, and as such a socioeconomic matter, land cover "denotes the physical state of the land." Land cover can refer to the type of vegetation occupying the land surface, physical features such as soils, or anthropogenic features like pavement (Moser, 1996). Land cover changes in two ways: conversion or modification (Turner & Meyer, 1994). Conversion is the transformation of one cover type to another, e.g., prairie to row crops; modification is a change in condition of a cover type, such as primary forest to high-graded forest.

The socioeconomic and biogeophysical realms of land use and land cover, respectively, are related via land management activities[2] (Figure 1). That is, landowner objectives implicit in land use are converted into altered land cover by management activities. For example, agricultural land use may convert the land cover from prairie to row crops with management activities: plowing, sewing grain, and perhaps applying pesticides.

Ecosystem goods and services provide a second connection between the socioeconomic and biogeophysical realms. In a general sense these are the products of land cover, consumed by landowners and other members of the public alike. Ecosystem goods and services are discussed further in Part II of the literature review.

Land use is subject to a number of forces influencing landowners, and the interaction of those driving forces that result in land use change and the resulting change

[1] Many works reviewed do not follow this terminology, and the phrases land use and land cover sometimes take on the same or different meanings; the degree to which a given work reflects the terminology described here tends to reflect the degree to which its author affiliates him- or herself with the academic field of land use/land cover change.

[2] The land use/land cover change literature employs the phrase 'proximate sources of change' to denote "those human actions that directly alter the physical environment" (Turner & Meyer, 1994). 'Land management activities' is the phrase used here for clarity's sake.

in land cover is the subject of the first part of this literature review. These are often referred to as human driving forces, "the range of social, economic, political, and cultural attributes of humankind that shape the direction and intensity of land use" (Turner & Meyer, 1994).

1.2 Approach and structure of the review

This review of driving forces of land use change begins with a lengthy discussion of population growth and its direct and indirect influences on land use and land cover in the Southeast. This first section illustrates the decision-making process of individual landowners, and is followed by a consideration of how a host of policies purposely or unintentionally influence these decisions.

Economic analyses are well-represented in the land use/land cover change literature, and for good reason. Economic models are or particular interest when examining land use change because they explicitly account for the decision-making process of the landowner. That is, economic models provide a formal description of how actors, in this case landowners, might behave in response to various factors deemed relevant to the analysis.

The approach taken by this review is to construct an expectation of how a landowner will behave in response to a particular condition or policy. The literature providing empirical evidence for or against the hypothesized relationship is then discussed.

Literature on topics relating to the drivers of land use change is extensive, and as a result the review emphasized recent research from the 1990s onward, although some earlier works are cited where particularly relevant. Studies focusing on the Southeast are complemented by relevant studies from other parts of the U.S. The agricultural economics literature is tapped to obtain some land use policy lessons. There is an abundance of literature relating to land use that is entirely anecdotal, descriptive, or prescriptive. These works are generally avoided, as are entirely theoretical papers from the economics literature.

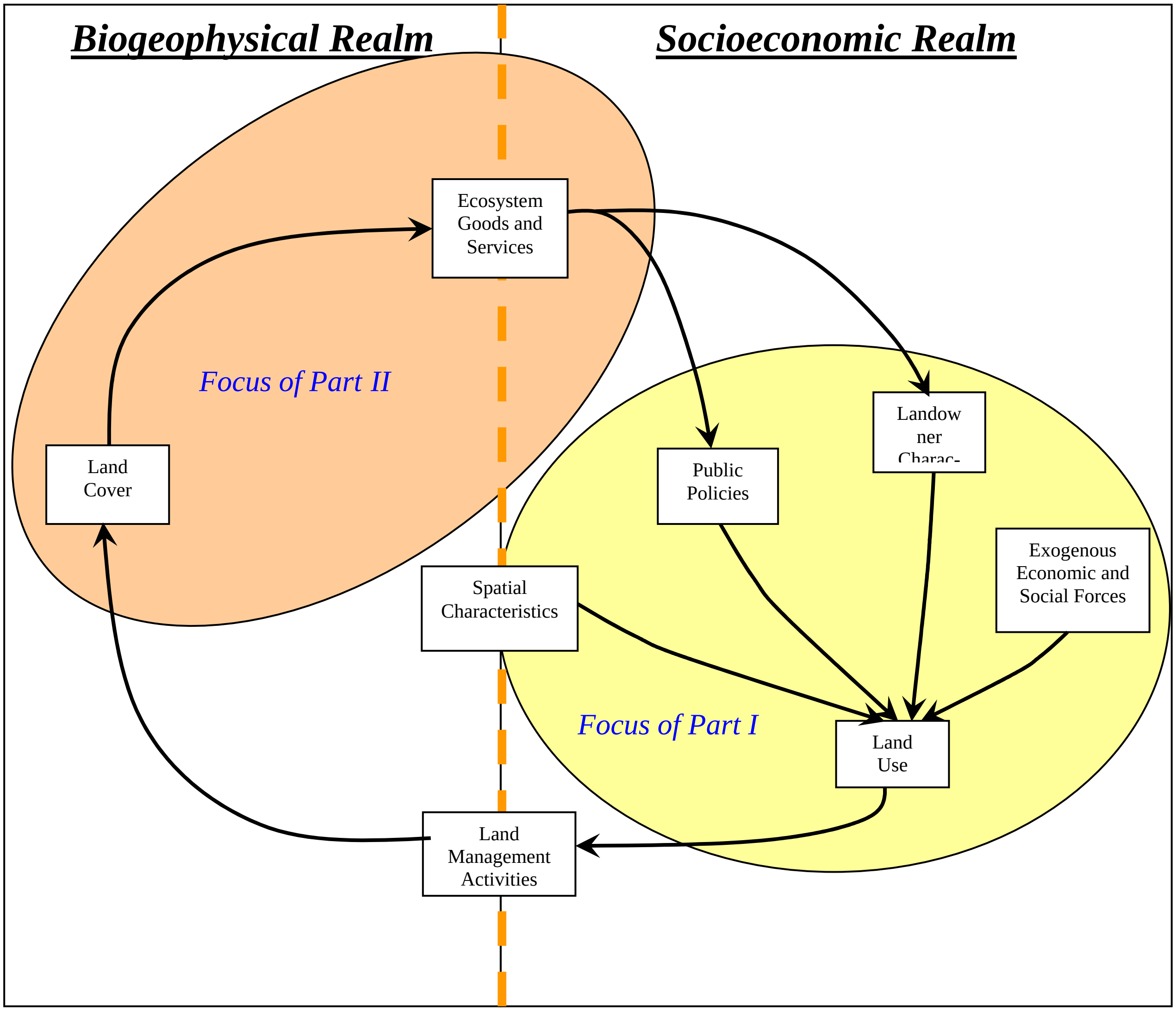

Figure 1: Relationships between the biophysical realm (land cover) and the socioeconomic realm (land use). Adapted from (Ojima *et al.*, 1994).

2

THE SOUTH'S POPULATION IS GROWING

While not a driver of land use decisions itself, the overarching macro-socioeconomic phenomenon of population increase in the South has so many direct and indirect effects on land use drivers that it merits lengthy treatment. The U.S. as a whole grew 25% between 1980 and 2000, an increase of over 56 million people, and the South is one of the fastest growing regions in the country (U.S.Department of Commerce, 2001). One analysis projects that by 2025 developed land in the U.S. will expand by 79%, and in the South will increase 75% (Alig *et al.*, 2004). The study finds that rising incomes and population growth largely explain land conversion to urban uses throughout the country. Ten million acres are predicted to be converted to urban use in the South while forest cover declines by six million acres in the region by 2030 (Alig & Platinga, 2004).

The two studies mentioned along with (Ahn *et al.*, 2002) provide a useful long-term, large-scale perspective of land use/land cover change in the U.S. Nevertheless, the relationship between population growth and land use change is richer than indicated by these analyses: population and income growth set in motion a series of events that both directly and indirectly influence the behavior of a large group of individual landowners. Figure 2 presents a web of hypothesized relationships between the changing demographic and economic makeup of the region and its land use and land cover outcomes. Arrows in the figure imply causation, and throughout the body of the text this network of relationships will be elucidated via the reviewed literature.

2.1 What is happening to the South's forests?

Aside from the outright conversion of forests to urban uses mentioned above and discussed at length further on, land in the South typically transitions between agricultural and forestry uses, often between row crops or pasture and planted pines (Alig *et al.*, 2004). Land in the South is also increasingly parcelized, that is, experiencing the "general shift from a few landowners with large landholdings to many landowners with smaller holdings" (Mehmood & Zhang, 2001, p. 30).

Parcelization has two central consequences: it diffuses ownership of forestlands, and it alters the production environment of forestlands[3]. The change in ownership and associated change in preferences and knowledge of forestland owners, as well as the impact of the costs and constraints of production will be discussed in Section 2.3, and the production consequences are treated in Section 2.4. We begin with a brief discussion of the causal factors involved in the parcelization phenomenon.

One author argues that the major drivers of parcelization are death, taxes, and lifestyles (DeCoster, 1998). Death often results in the transfer of forest estate ownership to multiple heirs, who may elect to divide the original parcel and whose preferences and land use objectives may be different than the original owner. Furthermore, some forest estates are subject to death and inheritance taxes, and empirical evidence indicates that

[3] Here production is taken to include both market and nonmarket goods and services.

these can be a significant driver of land cover modification and change[4]. Property taxes can be a significant cost for landowners that can increase in step with rising land values associated with regional population growth and urbanization. Finally, many Americans earning income in urban occupations exhibit strong preferences for living in and around forests. In the only comprehensive empirical study encountered, Mehmood & Zhang (2001) found that death, urbanization, local household income levels, and fear of regulation all contributed to parcelization, while financial assistance for forestland owners contributed to the maintenance of larger forest tracts.

2.2 The pervasive influence of land values

Land values have a direct influence on the behavior of forestland owners as they influence the financial returns to timber production and thus its competitive position relative to other land uses. Beyond its direct effect, the demand that results in rising land values generates a dynamic that makes up part of the "bow wave" of social and economic effects that precede further development in the region and have large impacts on forestland owners (DeCoster, 2000). This circular relationship where forestland conversion feeds back into expectations and further conversion via land values is illustrated by the orange arrows in Figure 2.

2.2.1 Land values and competition between alternate land uses

Recall that one useful way to think of a forestland owner is as a profit-maximizer. In order to maximize profits, the landowner may choose to maintain the land as productive forest, or convert it to another use such as agriculture or residential development. It is in this sense that alternate land uses compete: the landowner will tend to favor the land's "highest and best use," that is, its highest valued use in production of market goods.

Under this scenario, the landowner will maintain forest so long as the expected net present value (NPV) of forestry is greater than the expected NPV of converting to an alternative use. In the case of forestry, the NPV is the revenue generated from the sale of forest products less production costs. Land is an essential input to timber production, and the price paid for land thus takes away from the net return to forestry production.

Taxes based on land values are another important cost to landowners. Property taxes – generally based on the highest and best use of the land – represent an additional annual cost to timber production. Rapidly rising land values can also result in forestlands being subject to estate taxes upon death of the landowner, and these taxes have been shown to result in both unplanned timber harvests and outright sale of all or part of forestland estates. Both property and estate taxes are discussed further in Section 3.

In rapidly developing areas, even increases in the prices of forest products do not compensate for the spiraling costs due to rising land values. Rising land values thus diminish the competitive position of forests relative to other uses, and thus provide a powerful incentive for forestland owners in developing areas to convert to other uses.

2.2.2 Demand, development, expectations, and land values

[4] The economics of estate and property taxes including empirical studies of their effects are presented in Section 3.

In the absence of development pressure, and with a purely profit-seeking population of potential buyers, forestland value is typically conceived to consist of two components: the bare land value[5], and the value of standing timber (Beuter & Alig, 2004; Hardie *et al.*, 2004; Wear & Newman, 2004). A number of factors associated with increased demand for developable forestland and the expectations generated once the conversion process begins in an area can alter this simple relationship.

Four factors can combine to alter the demand for developable forestland, and this change in the demand relationship would tend to push land values upward[6]. First, a growing population translates into a direct increase in demand. This is fairly intuitive: people live beneath roofs and roofs and the lots upon which they stand take up space. Second, as discussed in Section 2.2 below, numerous studies have documented Americans' preferences for rural lifestyles (e.g., Kendra & Hull, 2005; Smith & Krannich, 2000 among many others). Evidence suggests that Americans also exhibit preferences for larger residential lots. Finally, incomes have been rising in the U.S. (U.S.Department of Commerce, 2001), and greater incomes provide additional purchasing power that enables individuals to acquire the relatively large residential lots common on the fringes of urbanizing areas. The total developed area per capita has been increasing everywhere in the U.S. except the west coast (U.S.Department of Agriculture, 2001). Income growth was shown to have contributed to suburban growth in the latter half of the 20th century in the U.S. (Margo, 1992). All of these demand factors push up the bare land value of forests, an upward trend that does not go unnoticed by forestland owners.

Beyond the general influence of increasing demand due to increasing population, certain attributes make some sites more attractive to development. For example, Cho & Newman (2005) found that greater proximity to roads and cities, greater access to surface water bodies, higher elevations, and flatter topography were highly desirable to rural land development. These desirable characteristics are in turn reflected in land values, with the corresponding influence on landowner decision-making.

Once development begins to take hold in an area, it generates expectations of how it will progress. These expectations manifest themselves in forward-looking land values that still reflect the value of the standing timber, but now also incorporate the expected value of the land in developed use, discounted from the anticipated development date (Hardie *et al.*, 2004; Wear & Newman, 2004). In developing areas, rapidly rising land values can readily diminish the competitive position of forestry and agriculture relative to developed uses.

The change in land values when expectations of development prevail is far from insignificant. Alig & Plantinga (2004) compared the returns to a typical sawtimber stand to returns to urban development based on values of recently developed parcels. They estimated that in the Southeast the weighted average land value in forest use was $415

[5] The bare land value represents the net discounted return to continuous timber production on unstocked land.

[6] In the familiar context of supply and demand curves, these factors would shift the demand curve rightward, resulting in higher equilibrium land prices.

versus a residential use value of $36,216[7]. Such a difference creates an enormous financial incentive for forest landowners to convert.

The forward-looking nature of land prices can be used to predict future development: once land values exceed a threshold level in a given area, the probability of the land's conversion to urban uses increases. Using a threshold price of $800/ac as the point where land use likely transitions from forestry to development, Wear & Newman (2004) evaluated assessed values for industrial timberlands and estimated that 6.4% (150,927 ac) of these tracts in Georgia would likely be converted to developed uses in 10-20 years. They further estimate that 10% (2.1 million ac) of all private forestland in Georgia currently exceeds the threshold value, and is thus susceptible to conversion. Employing projections of population, income, and farm earnings, they estimate that by 2010, 25% of the state's private timberland would exceed the threshold value.

Some have argued that once an area begins to develop, it becomes difficult to slow or halt the process due to the competition for land uses, and their influence on land values. Wear & Newman (2004) suggest that increasing bare land prices are an irresistible windfall, and many forestland owners can be expected to avail themselves of the opportunity and sell their land. As such transactions become prevalent in the local market, tax assessments based on fair market value increase, thus increasing annual costs and potentially forcing some owners to sell their property to avoid the elevated taxes. They thus argue that once conversion to developed uses begins it generates pressures that are difficult to resist.

2.2.3 The "impermanence syndrome"

The development premium incorporated into bare land values affects landowner decisions about investment in forestry operations (Kline *et al.*, 2004). The "impermanence syndrome," first discussed with respect to agricultural land conversion by Lopez *et al.* (1988), describes a situation where landowners act under the expectation that their land will ultimately be converted to urban uses. This shortens their planning horizon, and makes landowners reluctant to invest in new technology or land improvements since the land may be sold before the investment has a chance to yield positive net returns. Beuter & Alig (2004) describe the process as if land were a maturing fruit: "If owners are expecting that a higher and better use can offer more rewards in land markets, their propensity to invest in forest practices may be altered as they wait for the land to ripen for alternative use."

2.3 Changing ownership, changing preferences?

Different individuals can be expected to manage forestlands differently based on their preferences, and different societal segments tend to hold different preferences. Here we discuss the composition of the new forestland owner population, what is known about forestland owners' preferences generally, and how new and old owners may differ in terms of their motivations for owning forestlands.

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[7] The latter value does not represent the price a landowner would receive for the sale of an acre of land, but rather reflects the land in developed condition with infrastructure in place. Nevertheless, it does point towards a large difference in value between forest and residential use.

2.3.1 Who are the new forestland residents?

The change in ownership that has led to the wave of new landowners in rural forested areas is often called exurbanization, since these new owners generally have come from urban backgrounds and differ from long-time rural residents in important ways (Egan & Luloff, 2000). The studies surveyed here generally indicate that new residents are well-educated, relatively affluent, derive income from occupations unrelated to natural resources, are often retired, and of non-rural backgrounds. That is, results are generally consistent with Newman *et al.* (1996), who found that relative to longer-term forestland owners, new timberland owners in Georgia were wealthier, better educated, and have a better understanding of the investment opportunities associated with their land.

These characteristics are significant in that they affect landowner preferences, although the relationship is not always straightforward. Since income is tied to so many microeconomic behaviors, of particular interest may be the relationship between the source and level of income and preferences related to market v. nonmarket management. We could posit that wealthy owners with incomes not dependent on their land as less likely to harvest timber. One study reports that respondents whose income was more closely tied to their landholdings via farming activities were more interested in timber production and its resulting income (Haymond, 1988), consistent with the noted expectation. Another study found that wealthier forestland owners were both the most- and least-likely to harvest timber from their land (Kluender & Walkingstick, 2000). The results of these two studies indicate the nuanced role of nonmarket preferences in the land use decision of forestland owners.

2.3.2 What do we know about forestland owners' preferences?

Since preferences for different goods and services derived from forested landscapes are translated into management activities aimed at producing these benefits, landowner preferences influence forest cover everywhere. While much of the literature is anecdotal or prescriptive, a number of empirical analyses have examined preferences with an eye towards timber supply, assessments of policies affecting forestlands, as well as evaluations of how forestry services can be best delivered to landowners.

There is abundant evidence that forestland owners are interested in a variety of benefits from their land. Nationwide, forestland owners identify investment, recreation, timber production, and esthetic enjoyment as principal reasons for owning forestlands (Birch, 1996). Forestland owners in South Carolina indicated that income from forest products was secondary to lifestyle enhancement as the main benefit of forest ownership (Haymond, 1988). Erickson *et al.* (2002) found that aesthetics provided the strongest motivation for retaining woodlots in Michigan, and that environmental protection was a more important motivation than income generation from forests. Arkansas forestland owners held multiple objectives, many of them compatible with timber harvesting (Kluender & Walkingstick, 2000). Newman & Wear (1993) compared industrial and nonindustrial private forestland owners using an econometric model. They found that the behavior of both groups is consistent with a profit-maximizing motive, but that the production behavior of nonindustrial owners indicated that they derived significant nonmarket benefits from their holdings.

An additional consideration is the role of preferences beyond the personal benefits associated with forestland ownership. At least one study (Tyson *et al.*, 1998) indicates that forestland owners do consider the consequences of their management actions on the surrounding community, and another indicates that new landowners feel an obligation to maintain areas of their land for the protection of endangered species (Newman *et al.*, 1996).

2.3.3 Are new and old forestland owners different?

A major theme in the literature has been that long-term landowners were more oriented towards “traditional forestry” – generally taken to mean regarding forestlands as timber-producing income generators – than are new forestland owners. New residents within forested landscapes may tend to value forests for different ends, often recreation or wildlife rather than timber production (Kline *et al.*, 2004). This could lead to compositional changes in forest cover that reflect these new landowners’ preferences for nonmarket goods and services. A common account of this shift argues that forested regions are increasingly becoming populated with residents who prefer natural beauty, wildlife, and recreation over the “traditional,” i.e., productive income-generating, uses favored by long-term residents (Smith & Krannich, 2000).

It is not clear how much change in objectives results from changing ownership. For example, it is generally held that new forestland owners are more environmentally concerned than longer-term forest landowners. The forestry industry tends to hold this view, although a survey of forest landowners in Pennsylvania indicated that they were more aptly described as environmental activists (Bliss, 1994; Luloff *et al.*, 1993, cited in Jones *et al.*, 1995). The Jones *et al.* (1995) paper further notes that landowners tend not to be timber-oriented in their land use decisions, and that although they are concerned about a potential loss of property rights resulting from regulation, they do recognize the social responsibilities arising from land ownership. New and old landowners are considered by many to differ on these points as well, but that conclusion seems questionable and evidence suggests that the preferences of new forestland owners may not be as different from longer-term forestland owners as once believed.

The possibility remains that longer-term forestland owners are not that different in terms of preferences and opinions than the pool from which new forestland owners are being drawn, i.e., the general public. For example, (Bliss *et al.*, 1994) found that forestland owners in Tennessee reflected the public in their opinions about the environment and economy, a similar result to that found in Alabama surveys (Bliss, 1993, cited in Bliss *et al.*, 1994). The notion of the existence of a traditional forestry community possessing views differing greatly from the rest of society seems questionable.

Relatively few studies have focused on new forestland owners, thus making it difficult to determine whether differences between new and old forestland owners are perception or reality. Ryan (1998) found that new residents in a forested and agricultural watershed in Michigan demonstrated preferences for natural landscapes, in contrast to longer-term residents who showed preferences for domesticated landscapes.

Newman *et al.* (1996) found that new timberland owners in Georgia shared many of the same objectives of the broader population of forestland owners, with the exception that they placed a higher value on recreation and hunting opportunities[8]. The new forestland owners regarded timber, wildlife, and recreation opportunities as primary activities that will occur on their land, and placed timber and recreation as the strongest overall reasons for their land purchase.

Kendra & Hull (2005) used segmentation techniques familiar in the marketing field to assess the motivations and forest management practices of new forest owners in rapidly-growing Virginia counties. The study surveyed owners of recently-purchased forestland from 2 to 50 acres in extent, and grouped them into six segments, such as "absentee owners," "forest planners," or "young families." Relatively few respondents resembled the perception of the traditional forestland owner, and none of the segments considered profit as being an important objective. Rather, lifestyle considerations such as simplicity, spirituality, nature preservation, and regionalism were principal motivations.

Differing backgrounds do not necessarily translate into differing attitudes towards the environment or land use. Smith & Krannich (2000) found that although they varied from long-term residents on a number of socio-demographic dimensions, newcomers held largely similar views on land use and the environment. Contrary to what is often reported in the media, their results indicated that long-term residents were more concerned about local population growth and economic development, and were more interested in limiting these processes than newcomers.

The owners of large forested tracts may have preferences that differ from small- and medium-scale landowners that may result in different forest management and composition outcomes. Large tracts are of increasing importance in an increasingly parcelized landscape. Large landowners however, may not be different in terms of attitudes regarding forestry practices and the environment. (Jones *et al.*, 1995) consider this view a myth, and argue that large landowners hold similar views on the environment, forestry, and regulation as smaller forestland owners and the general public. They note that large landowners are more likely to support banning clearcuts and that few hold their forestlands for the purpose of income generation (Luloff *et al.*, 1993, cited in Jones *et al.*, 1995).

2.3.4 Are new owners' preferences reflected in management actions?

It is not clear the degree to which new forestland owner preferences translate into activities that enhance the output of desired benefits from forests. Although 74% of the respondents in the Kendra & Hull (2005) study were first-time forestland owners, many were undertaking management activities on their lands that reflected their stated preferences. 45% of respondents reported having already taken action to improve wildlife habitat, 24% had already pruned or cut forest stands to improve forest health while 13% had done so to improve timber, and even prescribed fire had been used by 9% of respondents.

Erickson *et al.* (2002) found that increasing forest cover in agricultural/forested watersheds in Michigan was tied to changes in ownership from farm owners to non-farm owners. In this case, the management action taken appears to have been a "hands-off" approach rather than active establishment or management of woodlots.

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[8] The authors note that the study surveyed owners of 75 or more acres, a subsample representing only 5-10% of the broader forestland owner population.

2.4 Changing owners, changing knowledge and ability?

New forestland owners may lack sufficient knowledge and abilities in two important areas: first, how to manage their forestlands, and second, how to conduct themselves in market transactions such as land and forest products, or the contracting of management services.

2.4.1 Do landowners have the knowledge to achieve their management objectives?

Changing ownership can result in many first-time forest landowners (Kendra & Hull, 2005). These new landowners may have little familiarity with many important management issues, such as forest health and wildfire considerations. Managing forestland for a given objective can be an inexact science even for experienced professionals, and it is not clear whether first-time landowners will be as effective as experienced landowners, or whether they may avail themselves of the services of trained professionals.

While landowners may pursue different land uses based on their preferences for the goods and services provided by forests, they may not reach their objectives if their knowledge of their management actions is inadequate. Egan & Jones (1993) compared the attitudes toward, knowledge of, and assistance with forest stewardship to impact and mitigation variables measured on the ground in their harvested woodlots. The study found that landowners' expressed level of land ethic resulted in little difference in management of their forest harvests, while landowner knowledge of forest ecology and management did lead to lower harvesting impacts and greater mitigation of negative effects on surface water, roads, and skid trails.

Unsound management practices resulting from the questionable practices of unscrupulous loggers can have far-reaching impacts on forests both in terms of their composition and their associated economic value (Nyland, 1992). While it is clear that timber harvest is not the primary objective of most forestland owners, a lack of knowledge about forestry practices can lead to land cover change in the form of changing forest composition. The new landowner distrust of both private and public sector forestry professionals found by (Rickenbach *et al.*, 2005) mirrors that found by (Kendra & Hull, 2005).

This is unfortunate, as the use of foresters and logging contracts did appear to reduce timber harvest impacts in one study, although it had no influence on mitigating the negative effects on surface water, roads, and skid trails (Egan & Jones, 1993). "Highgrading is so common because most landowners do not have adequate knowledge of forests and forestry. Too often, their woodlot management decisions are made in an information vacuum" (Jones *et al.*, 1995).

Landowners do avail themselves of the services of forestry professionals, but lack of experience with forest management may put them at a certain disadvantage. One author argues that forestland owners are subject to a catch-22 when dealing with professional expertise (DeCoster, 1998): most landowners only rarely seek professional expertise because it only rarely becomes relevant to them; when circumstances warrant professional expertise, they may not know how to find it because they have not consulted before. When new forestland owners in Virginia were asked to identify constraints to independent management action, 26% noted that they did not how to do some activities, and 17% did not know where to get advice about management activities (Kendra & Hull, 2005).

2.4.2 Information and land, forest products, and forestry services market transactions

Information is important when conducting market transactions, and since many forestland owners view their properties at least partially as investments, informed decisions about management activities such as stand improvements or timber sales may be a key to their success[9]. First-time forestland owners lack the experience that informs decisions, and this may translate into a compromised bargaining position, for example when negotiating stumpage prices as part of a timber sale. As noted above, landowner inexperience and lack of management knowledge has the potential for large forest compositional consequences.

The land cover consequences of substandard returns to investment from forestlands are unclear. One outcome may be that if landowners perceive that they are being taken advantage of, they may be reluctant to sell timber or conduct management activities directed at nonmarket goods and services. In any case, new forestland owners in one survey showed a surprising lack of utilization of outside information when purchasing forestlands (Newman *et al.*, 1996). A large number of respondents indicated concern about their investment, but over 40% did not consult anyone when purchasing their forestland.

Rickenbach *et al.* (2005) surveyed largely new, exurban members of a small-scale forest landowner cooperative in Wisconsin. The authors contrast these "active" forest landowners with the more typical "passive" owners, i.e., those whose main objectives include recreation, aesthetics, or wildlife. They found that members were motivated to join the cooperative for two reasons: first as a reaction to their disadvantaged position relative to forestry industry operators when conducting transactions such as timber sales, and second as an alternative to the state's primary government tax incentive program that required approved forest management plans whose principle objective was timber production.

The study indicates that at least some new forest landowners are more than just babes in the woods. It confirms that some recognize key economic considerations for forest ownership and management: both the scale production diseconomy and the information disadvantage of the individual landowner in forest products markets. The authors believe "that new forest owners will continue to challenge and reshape the status quo to meet their vision of forests and expectations of forestry" (Rickenbach *et al.*, 2005, p. 10).

2.4 Changing landowners, changing productive environment?

The influence of new landowners may extend beyond their property boundaries. Some hold that conflicts between exurban migrants and forestry operations may arise, or that new landowners may influence local governments to enact new forestry

[9] See Akerlof (1970), a classic paper considering the used car market as an illustration of the importance of information in market transactions.

regulations[10]. In either case, production costs could be expected to increase, once again diminishing the competitive position of forestry use. Although the mechanism is not always clear, increases in rural population densities do influence management behavior. For example, in a four-county study in Virginia, Wear *et al.* (1999) found that a given tract of land had a 75% chance of being under commercial forest management when population densities were 20 persons/sq. mile (psm). The chance of land being subject to forest management was 50% at a population density of 45 psm, and further decreased to 25% at 70 psm.

2.4.1 Rural-urban conflicts

Kline *et al.* (2004) indicate that conflicts might take the form of vandalism of equipment or infrastructure, trespass and associated liability issues, or complaints arising from management practices such as clearcutting or prescribed burning. They note however, that there is little evidence linking population density and the likelihood of forest-urban conflicts (Schmisseur *et al.*, 1991 cited in Kline *et al.*, 2004).

2.4.2 Exurban migrants, lifestyles, and local regulation of forest management

The contention that exurban migration leads to local forest management regulation seems to have some support. Martus *et al.* (1995) argue that former urbanites have few ties to agricultural and forestry land uses and feel that unregulated forest management threatens the high-amenity lifestyle that they seek when moving to rural areas; Cubbage & Raney (1987) reached a similar conclusion. They thus anticipate an expansion of local regulation of private forestry in coming years.

Compliance with forest management regulations is not without cost. For example, complying with water quality regulations during harvesting operations in Alabama, Florida, and Georgia was found to reduce gross harvesting revenue by 3% (Lickwar *et al.*, 1992). According to Ellefson & Cheng (1994), "Local ordinances can become a jungle of complexity and inefficiency," (p. 34) and studies of mandatory and voluntary forest practice guidelines consistently find that they impose significant costs on both private landowners and the government agencies enforcing them (Cubbage, 1995). Regulations such as special feature protection, environmental protection, and timber harvesting have the greatest potential impact on forest management and have been the most prevalent new regulations during a four-fold expansion of local regulations during the late 80s/early 90s (Martus *et al.*, 1995).

While there appears to be solid evidence that increases in local forest management regulation is linked to exurban migration, the impact of these regulations on forestry operations in urbanizing areas is less clear. As (Cubbage, 1995) notes, "both advocates and opponents of regulation often rely on rhetoric more than research." (p. 16). As noted in Section 3, federal regulation of endangered species has clearly altered landowner behavior. Local regulations presumably do increase forest management costs, thereby diminishing the competitiveness of forest uses, but this has yet to be documented via collection of primary data from landowners or managers.

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[10] Forest management regulations constrain the behavior of landowners. Although the focus here is on formal constraints, there is also an abundance of informal constraints to behavior (North, 1990). For example, a "beauty strip" alongside a roadway may not be required when harvesting a timber stand, but its omission may lead to citizen opposition to future timbering activity.

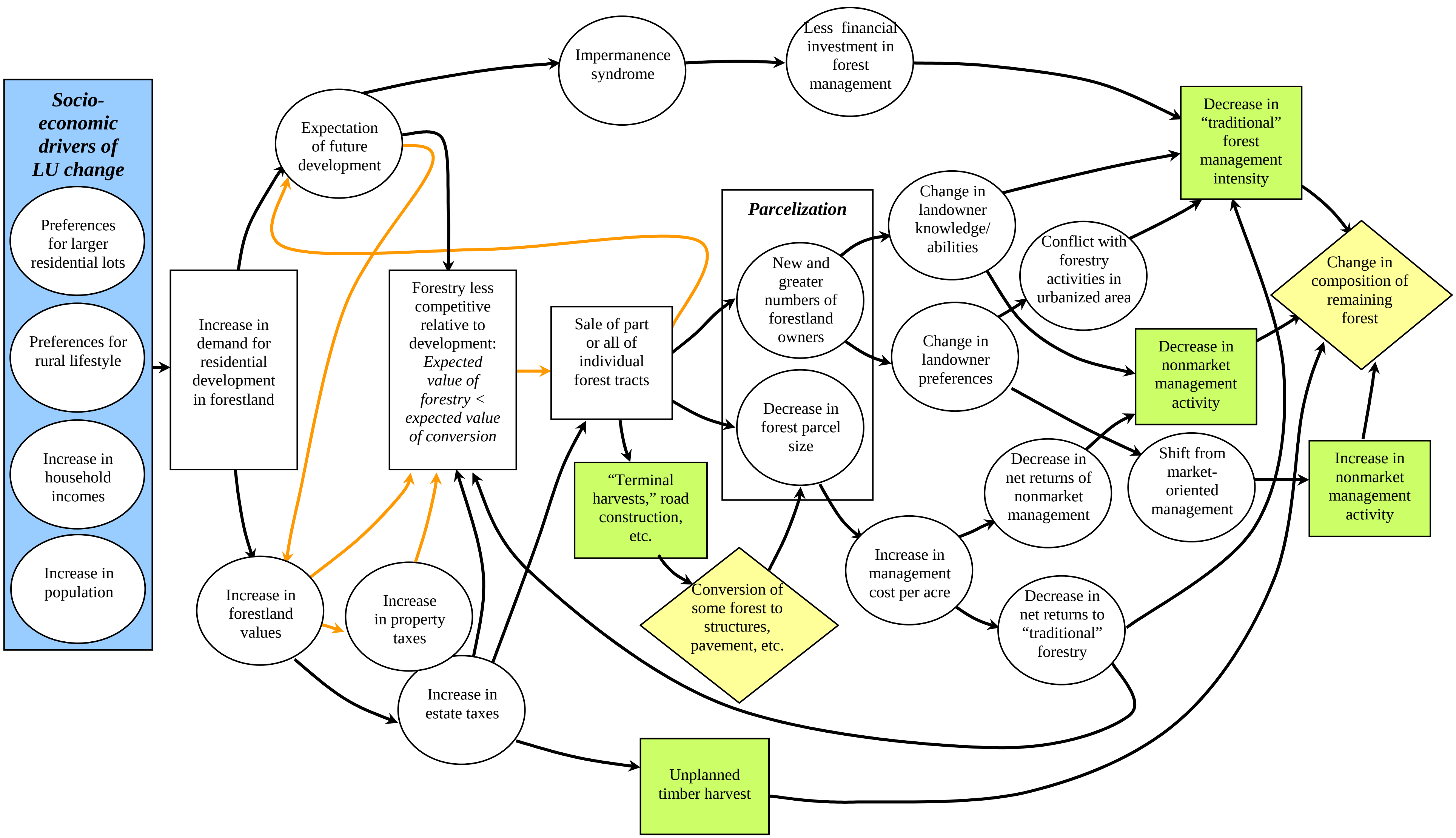

Figure 2: The direct and indirect influences of population and income growth. Arrows imply causation; land management activities are shaded green; land cover outcomes are shaded in yellow.

3

POLICIES AND THEIR INFLUENCE ON LAND USE

Public policy can affect land use and land cover in forested and agricultural landscapes. For example, in a two-county region in Southern Illinois, 6% of eligible private acreage has been enrolled in the Illinois Forestry Development Act (IFDA) landowner assistance program (Carver *et al.*, 2006). The IFDA couples property tax discounts (taxes are based on 1/6 of the enrolled land's assessed value) and cost sharing for tree planting and forest management (up to 75% cost reimbursement). Although the Carver *et al.* (2006) study's objective was not to evaluate landowners' decisions, and thus it is not clear whether either property tax relief or cost sharing are more or less important, the program enrollment result does provide a proxy indicating that the IFDA has influenced the land use decision on a significant scale.

While many policies are developed with the intention of steering land use, some policies with different motives also impact land use and land cover. As Fulton *et al.* (2006) note, "It is not difficult to conclude that growth management tools, consciously or not, do have an impact. It is very difficult, however, to measure exactly *how* these factors affect metropolitan growth." (p. 3; their emphasis). The discussion that follows emphasizes the "how" of the above remark, and begins with a major set of policies that unintentionally affect land use and land cover: income, property, and estate taxes. We then proceed to a consideration of a few policies aimed at affecting urban growth, and a handful of other policies affecting forestland owners. Intentionally or not, policies influence many of the relationships elaborated in Section 2; below the mechanisms by which they are intended to function are considered, and the empirical evidence of their efficacy is evaluated.

3.1 The unintended impacts of taxation

Taxes affect land use, as Moffat & Greene (2002) note, "the land itself is taxed annually, income derived from the land is taxed, the transfer of land and other assets from one generation to another is taxed, and, in several states, the act of removing timber or minerals from the land is taxed" (p. 42). None of these taxes were designed to influence land use and land cover, but all of them do to varying degrees.

3.1.1 Income taxes and the variable cost of forest management

Both federal and state income taxes affect forest landowners' decisions. Since state tax rates are typically much lower than federal rates – or in the case of Texas and Florida, nonexistent – they have less influence than federal taxes (Bailey *et al.*, 1999). In any case, Moffat & Greene (2002) argue that the federal income tax is the single most important tax on rural working landscapes in the South. Both state and federal income taxes affect landowners in the same way: they increase the variable cost of producing forest products, and as a result decrease the expected value of forestland thus diminishing its competitive position relative to other land uses.

Income from timber sales is treated as a long-term capital gain and thus subject to a maximum rate of 20%, while the sale of other forest products is treated as ordinary income and subject to tax rates up to 39% (Haney *et al.*, 2001). Bailey *et al.* (1999) estimated income tax effects on a typical Southern forestland owner, and determined that up to one-third of timber sale revenues can be lost to federal and state income taxes. This need not be the case, as they found that tax liabilities can be substantially decreased, although the services of professionals experienced in forestry tax provisions is generally necessary. Forestland owner awareness of tax provisions that work in their favor varies (Greene *et al.*, 2004). Nearly 80% of surveyed forestland owners in South Carolina were aware of the long-term capital gain treatment of income and annual deductions for management costs, but other provisions such as exclusion of cost-share payments were familiar to far fewer (42%) landowners.

No research was encountered that provided any empirical indication of federal or state income taxes' impact on land use or land cover. That is, no study has surveyed landowners to determine the relationship between the financial impacts of income taxes and their land use decisions or their land management practices. Nevertheless, the taxation amounts are clearly large enough that they significantly affect the relative attractiveness of managing forests.

3.1.2 The current influence and uncertain future of estate taxes

Because both forest land and timber values have been steadily rising over the past several years, increasing numbers of forest estates are subject to inheritance taxes. In the absence of planning, financial needs resulting from estate taxes can result in unplanned timber harvests or the sale of forest lands. Large forested areas are potentially subject to this pressure in the coming years: Haney & Siegel (1993) note that the typical nonindustrial forest landowner is over 50 years old, and that nearly 20% are retired.

Greene *et al.*(2006) evaluated the effect of federal estate taxes on nonindustrial private forest landowners and found that forest landowners are disproportionately subject to the federal estate tax relative to the general population. Nine percent of respondents to a national survey reported having been involved in an estate transfer between 1987 and 1997, and 38% of these were subject to estate taxation compared to 2% for estates in general. Of affected forest landowners, 22% sold timber to pay for all or part of their estate taxes, while 19% sold land in order to cover their tax bill. Based on the mean harvest area (498 ac) and mean sale area (387 ac), they estimate that 2.4 million acres are harvested annually and 1.3 million acres are sold each year to pay estate taxes[11]. Furthermore, 29% of sold acreage was developed or converted to another use. That is, the estate tax drives millions of acres of land cover modification, in addition to approximately 400,000 acres of conversion annually.

Some estates are also subject to "special use" valuation[12] similar in spirit to preferential property tax policies (Greene *et al.*, 2006). Special use valuation during the survey period[13] allowed forest landowners to reduce the gross estate value up to $750,000, although this valuation status is of limited applicability and moreover precludes timber harvest for 10 years. One-third of surveyed forest estates qualified for this treatment, and only 26% employed special

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[11] The authors rightly note that the extension of their survey response to all forest landowners should be considered indicators of magnitude rather than precise estimates since they surveyed members of national landowner groups, and while the total response to the survey was relatively large, the sample sizes used for some of the estimates are small.

[12] Special use valuation refers to real property valued for federal estate tax purposes on the basis of its current use rather than its highest and best use. Special use valuation requires that property be in use as a farm for farming purposes, or as a closely held trade or business other than farming (Haney & Siegel, 1993).

[13] Federal estate tax legislation is contentious and dynamic; see box on p. 16 of (Greene *et al.*, 2006) for details. Currently there are congressional proposals both to eliminate the federal estate tax or substantially increase the lower bound of its application (Mullins, 2006).

use valuation to reduce their gross estate value by an average of $325,000. Although it surely translates into reduced land cover modification and conversion on an estimated 20,000 forest estates annually, the total area affected by special use valuation is not clear from the survey results.

The role of estate planning in preventing the disruption of forest management or conversion of forest lands is highlighted by Peters *et al.* (1998), who evaluated the estate and death tax effects on forest estates in 14 Midwestern states. They reported that advanced estate planning techniques such as gifting, minority discounts, special use valuation, and deferral and extension of estate tax payments can reduce tax burdens by 77%. For those families unable to avail themselves of some planning techniques such as special use valuation, conservation easements can also reduce tax payments because they ensure that forest land is valued at its present use rather than fair market value. Landowners do employ professional services to alleviate some estate tax burden, Greene *et al.* (2006) found that 64% of decendent owners used financial or legal assistance to plan their estate.

3.1.3 Rising land values, rising property taxes, and the competitiveness of forestland

The suggestion that rising property taxes resulting from rising land values is a major causal factor in conversion has been advanced by many (DeCoster, 1998; Wear & Newman, 2004, among others). Since property taxes diminish the expected returns to forested land uses, we would expect that higher tax rates would encourage conversion to urban and suburban uses.

Limited empirical results from the literature however, indicate that this relationship may not always hold. Higher rates of property taxation were found to be more effective than zoning regulations in delaying agricultural land conversion to residential, industrial, and commercial development in Delaware County, Ohio (Hite *et al.*, 2003; see also Templeton *et al.*, 2006)[14]. Empirical results of the study indicate that increases in either component of the overall property tax, infrastructure or school taxes, delayed conversion. Policy simulations conducted estimate that a 20 percent increase in school taxes translates into a 17-month delay in conversion of agricultural parcels, while the same percentage increase in infrastructure taxes would have a much greater effect, delaying conversion by 5.7 years[15]. Higher levels of property taxes were also found by Irwin & Bockstael (2002) to modestly delay land conversion in Maryland.

3.1.4 Giving landowners a break: current use valuation

Current use valuation, or preferential property tax assessment, is a policy response to the land use consequences of rising property taxes in developing areas, and as such is our first example of a policy explicitly intended to steer land use. All 50 states have some property tax program that gives special consideration to forests, and these programs generally apply to farmland as well. The two most common tax policies affecting forest properties are current use programs that assess the land's taxable value as per its use as forest, and ad valorem laws that discount the full fair market value of the forest land by a predetermined percentage; 36 states (9 in the South) have enacted the former and 15 the latter (Hibbard *et al.*, 2001). Such programs have a mixed record both in terms of state administrators' judgments of achievement and measurable impacts of altered landowner behavior.

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[14] Need to put a footnote in somewhere about survival models and land use change.

[15] The authors speculate that school taxes have a relatively lower impact than infrastructure taxes because school quality is an important factor in residential location decisions; higher school taxes may imply better schools, and thus more attractive locations for residential development.

A nationwide survey of state administrators of private forestry programs indicated that forest tax programs were "only modestly conforming to standards commonly used to judge tax policy" (Hibbard *et al.*, 2003). Furthermore, the respondents felt that the programs were only modestly accomplishing the objectives for which they were created. These objectives included long-term investment, "sound, practical, and scientifically-based forestry," timber production, and nonmarket benefits such as wildlife habitat.

Preferential tax treatment "works" on the ground if it affects forest landowner behavior. With respect to their influence on the land use decision by farmland owners, Heimlich & Anderson (2001) note that "Preferential assessment removes a disincentive for conserving farmland in the face of development pressure by assessing the property at its value in agricultural use, rather than the higher developed land values found near cities, often in exchange for an agreement not to develop for some period" (p. 60). They conclude that this most common of farmland preservation techniques is a popular subsidy for farmland owners that has not resulted in a strong incentive to conserve farmland. This is consistent with the Brockett & Gebhard (1999) study that concluded that landowners participating in the Tennessee Greenbelt program have received a windfall without delivering any return to the citizenry, and that this is true even where development pressure is highest.

The sentiments of respondents to the Hibbard *et al.* (2003) study seem to reflect the findings of a number of studies evaluating landowner behavior. Tennessee's Greenbelt program is one example of a preferential assessment policy. Participants may harvest timber, but may not convert the land to commercial or industrial use, and may not sell to someone who does. Brockett & Gebhard (1999) conducted a survey in one Tennessee county where the program yielded tax savings of 38% to participants, and compared the attitudes and behavior of forest landowners participating in the program with nonparticipants located nearby. The comparison indicated that their behavior was essentially the same: no differences were detected between the two with respect to plans to develop their land or harvest timber in the coming decade, past timber harvesting or silvicultural activities, or management objectives. That is, the preferential tax treatment has had no effect on land use or land cover.

Morris (1998) evaluated 3,000 counties around the U.S. and found that, over the course of 20 years, approximately 10% less of a given county's farmland had been converted thanks to preferential assessment. She further noted that tax burdens are minor compared with potential returns to development in urbanizing areas, and that as a result preferential assessment cannot be expected to halt conversion.

Newman *et al.* (2000) evaluated the first five years of implementation of Georgia's Conservation Use Valuation program, a program that allows current use valuation for 10 years on private land dedicated to agriculture or forestry, or land deemed environmentally sensitive or in transition to residential use. A significant area of forestland has been enrolled in the program, 22% of eligible land in north Georgia, indicating that forestland owners are certainly willing to reduce their tax load[16].

[16] The study's results regarding landowner participation are in a sense less important than the author's observations about who *cannot* participate in the program: corporate landowners and large (2,000 or more acres) landowners. The exclusion of these landowners means that their tax assessments on holdings in developing areas are likely to exceed the level at which they can sustain forestry production, and thus their lands are more likely to be converted to residential or other developed uses. As a result "the long-term impact on traditional land uses and regional green space brought on by differential taxation based on ownership and quantity of land may well be negative" (Newman *et al.*, 2000), p. 266.

Hickman & Crowther (1991) estimated the effects of current use valuation on participating landowners in East Texas and assessed the state program's effectiveness at encouraging the retention of qualifying lands in forested use. Forestland owners enrolled in the program were receiving significant tax relief, reducing taxes due on timberlands by 79%. They found that the greatest level of tax relief, i.e., the greatest reduction in taxes due, occurred in urbanizing areas where development pressure was greatest. However, participation in these urbanizing areas was lower. They concluded that "left unanswered is the question of how Texas' current use programs are affecting land use decisions" (p. 19).

3.2 Steering the development of the landscape: local and regional growth control and management

Policies may be aimed at either controlling urban growth or preserving or enhancing some environmental feature, although the two are inextricably linked (Hollis & Fulton, 2002), and many policies recognize both objectives. The growth management literature is long on description of policy instruments and short on empirical evaluations of their impact. The relatively few empirical works in the literature often have a narrow focus and may be of limited value when considering policies outside their scope (Bengston *et al.*, 2004). This is further complicated by difficulty in separating the effects of institutional implementation from the effects of the policy instruments themselves (Carruthers, 2002). Explicit treatment of landowner behavior in response to growth management policies is particularly rare, as most of the literature considering policy impacts focuses on such outcomes as housing prices, urban lot sizes, and the like.

Some evaluations do indicate the effects of growth management on land use decisions. For example, Nelson (1999) compared two states with growth management, Florida and Oregon, to a similar third state without growth management, Georgia. Nelson's assessment focused on some broad outcomes of growth management using indicators from the 1980s and 1990s. The analysis indicated that Oregon and Florida were better at controlling urban sprawl, consumed less farmland per new resident, provided more transportation accessibility, consumed less energy, and minimized tax increases relative to Georgia. In any case, growth management is a topic of interest to many for a number of reasons, and the policy environment is relatively dynamic; see American Planning Association (2000) for recent policy developments throughout the U.S.

3.2.1 Why growth management?

Land use regulations have three basic and interdependent objectives that represent the fundamental motivation behind most growth management programs: maintaining residential property values, shaping a compact urban form, and promoting efficient public service provision (Carruthers, 2002). Policies are intended to raise real estate values by protecting against negative externalities such as congestion and incompatible land uses, although whether this is a worthwhile planning goal is contested. Compact urban form is viewed as beneficial because it increases regional equity, preserves outlying resource lands, and makes public transportation possible. Greater urban density also generally allows for lower-cost provision of public services, while diffuse exurban development is often costlier.

3.2.2 Local vs. regional interests and management

Carruthers (2002) notes that over the course of the latter half of the twentieth century growth management has undergone a transition from narrowly conceived local growth control policies detached from state-level land use legislation. Of late, "second generation" growth management efforts have converged in the form of state-based growth management programs and regional planning organizations. An important distinction of these contemporary efforts is that they focus on containing urban sprawl but recognize the need to accommodate growth through coordinated, well-planned land use[17]. State and regional policies are generally aimed at leveling the regulatory landscape by setting standards and specifying the use of policy instruments. These policy instruments are in turn implemented and enforced at the local level by local governments and act as "the workhorses of growth management."

Clearly, local governments are essential to growth management since they inhabit the interface where land use drivers are translated into land use decisions. Nevertheless, exclusively local governance of growth can lead to outcomes that are undesirable on a regional scale since local governments act upon their narrow interests that may not be aligned with optimal regional outcomes. Fischel (2004b), for example, argues that zoning laws result from the influence on local government of homeowners seeking to protect the value of their principal financial asset: their home. One hypothesized outcome is that when growth management policies are not uniformly applied across a region, land markets become segmented and growth is shifted from areas with more restrictive regulation to jurisdictions with less restrictive regulation, and therefore lower conversion cost.

The hypothesis appears to have some support. Shen (1996) evaluated the region-wide spatial consequences of locally-enacted growth controls in the San Francisco Bay region. The study found that local policies caused a major redistribution of population growth from those cities with growth controls to elsewhere in the region. The author argued that local growth control is driven largely by the narrow interests inherent in NIMBYism. Pendall (1999) found that while development impact fees led to greater urban densities, their overall impact depended on the consistency of their application across the region. Relative to regions where they prevailed, regions where few communities enacted impact fees saw limited effect from the policy. Highly fragmented, localized growth management in metropolitan regions throughout the U.S. was found by Carruthers (2003) to promote urban sprawl by increasing the proportion of growth occurring outside of incorporated areas.

At the same time there is evidence that regional planning efforts can yield better outcomes. Carruthers & Ulfarsson (2002) argue that even though regional planning organizations may not have direct authority over local governments, their oversight of transportation spending means that they have considerable influence over land use since transportation infrastructure can have a powerful effect on local land use. Investment in travel infrastructure makes travel faster and more convenient, reducing the cost of commuting to relatively cheaper suburban and exurban housing, and thus making these locations more attractive and leading to spatial expansion of developed areas (Brueckner, 2000).

3.2.3 Specific land use policies

Transportation infrastructure

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[17] Carruthers (2002) distinguishes growth control from growth management. The former refers to "measures aimed specifically at regulating the pace and amount of growth that takes place," the latter in contrast "encompasses a broader perspective, recognizing the need to channel growth in a way that promotes compact development and minimizes negative impacts."

Even the most cursory consideration of transportation infrastructure reveals that it significantly affects land use. Increased land values in locales proximal to transportation networks reflect the decreased transportation cost to residents and businesses afforded by highways (Boarnet & Haughwout, 2000). Transportation investment shapes residential, commercial, and industrial development patterns and determines the travel patterns of residents (Handy, 2005). The planning and construction of transportation infrastructure is contentious, as it is often implicated as a causal factor in suburban and exurban sprawl, although empirical proof of such a relationship is far from definitive.

Boarnet & Haughwout (2000) conclude that evidence suggests that highways do indeed influence land prices, population distribution, and employment near constructed transportation infrastructure, but "that the land use effects are likely at the expense of losses elsewhere." They argue that this influence on land use demonstrates transportation infrastructure's importance in directing the growth of urban areas, but does not imply that highways cause or contribute to urban decentralization.

Handy (2005) reviewed the empirical literature with an eye toward evaluating four propositions often forwarded regarding the relationship between transportation and land use: "(1) building more highways will contribute to more sprawl, (2) building more highways will lead to more driving, (3) investing in light rail transit systems will increase densities, and (4) adopting new urbanism design strategies will reduce automobile use." With respect to the four propositions, she argues that what can be concluded from the empirical literature is that: "New highway capacity will influence where growth occurs; new highway capacity might increase travel a little; light rail transit systems can encourage higher densities under certain conditions; and, new urbanism strategies make it easier for those who want to drive less to do so."[18]

Zoning

Zoning is a straightforward and traditional means of controlling growth. Fischel (2004a) argues that zoning began as a mechanism to protect homeowners in residential areas from devaluation by industrial and apartment uses that had become increasingly mobile thanks to the rise of trucks and buses in the first decades of the 20th century. With further advances in accessibility of automobiles and the interstate highway system, jobs and employees became even more mobile and zoning proliferated.

Whatever the causes of its proliferation, zoning appears to have at least as many detractors as proponents at present. Although zoning has been successful in generating and maintaining property values, it is often criticized as being exclusionary to low-income residents and ethnic minorities (Fischel, 1985, among others). Local zoning laws can be regarded as a case of self-regulation where the net benefits of regulation are captured by those being regulated (Altshuler & Gomes-Ibanez, 1993). Furthermore, the highly fragmented nature of zoning laws has contributed to the growth shifting that has led to less than optimal regional landscapes discussed above. In any case, zoning has often proved insufficient to meet the objectives of growth management, and as a result a number of additional regulatory techniques have been developed as complements or substitutes for zoning regulations (Carruthers, 2002).

Urban growth boundaries

States can designate boundaries within which urban growth may occur. While Oregon is the state best-known for its urban growth boundary policy, other states have adopted the

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[18] Handy's review (2005) discusses key works from the past 30 years. Rather than duplicating this thorough treatment only general conclusions are reported here; interested readers are encouraged to refer to this excellent review for much greater detail on the research evaluated to reach these conclusions.

legislation as well (Heimlich & Anderson, 2001). This type of policy affects the land use decision either by prohibiting or financially penalizing conversion of rural lands to urban uses outside the boundary, thus making rural uses the only acceptable land use or affording them a more competitive position relative to urban uses.

Kline & Alig (1999) found that development was concentrated inside Oregon's urban growth boundaries. Weitz & Moore (1998) found that development inside urban growth boundaries in Oregon tended to be more contiguous to the urban core, an outcome in line with the policy's desired pattern of more concentrated pattern of development. Nevertheless, a low-density ring of residential development has appeared at Oregon city edges (Nelson, 1994). Fulton *et al.* (2006) found that Seattle was largely successful in containing growth inside its strongly-defined urban growth area. They concluded that while urban growth boundaries can help to redirect urban growth, by themselves they cannot fundamentally alter urban form. On a regional scale, the effect of urban growth boundaries is a function of how much developable land is included inside the boundary: if too little is present it can be expected to create excessively high land values (Brueckner, 2000).

Beyond their influence on individual landowner decisions, urban growth boundaries have many impacts on local economic growth and development, and much of the literature has focused on these latter aspects. While growth boundaries can limit the footprint of cities, at the same time they can elevate housing costs, thus imposing a significant burden on lower income households (Quigley & Raphael, 2004). Among a number of effects related to housing markets in Portland, OR, (2001) report that growth boundaries created new special-interest groups that they believe will oppose growth-boundary expansion, including high-income hobby farmers who want to protect their rural lifestyle outside the growth boundary.

Adequate public facilities requirements

Adequate public facilities ordinances (APFOs) are used to limit new development until adequate public infrastructure is in place, and is a method used by communities to regulate the timing and pace of growth. Some argue that APFOs increase the cost of housing because supply is constrained by the delay in the provision of additional housing in growing communities. White & Paster (2003) posit that increased development costs may encourage sprawl by driving development of exurban areas where excess infrastructure is already in place. Expectations of future constraints on development may accelerate development so as to preempt its being subject to APFOs (Riddiough, 1997). Additionally, land values may fall due to expectations regarding the timing of installation of public infrastructure that ultimately allows for development. Some positive externalities may be associated with the delayed development by preserving communities' "quality of life" amenities capitalized into housing prices (Brueckner, 1990).

None of the studies mentioned above are empirical works however, and indeed no empirical works evaluating the effects APFOs were encountered in the literature. As a result, while the arguments discussed above seem reasonable, and it does seem likely that APFOs do affect land use, it is not clear exactly how this is so in actual practice.

Impact fees

Impact fees are charges levied by local governments on new development such that existing infrastructure can be expanded or new infrastructure constructed to accommodate the new development. They are generally calculated based upon some proportion of the additional infrastructure costs attributable to the new residence or business. While a number of papers have evaluated the effects of impact fees on housing prices and land values, two studies have quantified the effects of impact fees on land use. Skidmore & Peddle (1998) found that over a

15-year period in a northern Illinois county, impact fees slowed the rate of residential development by more than 25%. Mayer & Somerville (2000) evaluated 44 metropolitan areas in the U.S. from the mid-80s to the mid-90s and concluded that while regulations that lengthen the development process or constrain new development in other ways can greatly depress the new housing starts, impact fees had little effect on new housing construction.

Designated priority funding areas

Local governments can establish priority funding areas (PFAs) that channel funding for infrastructure towards concentrated areas (Heimlich & Anderson, 2001). Such policies should lower the expected return to development of rural lands by increasing the infrastructure costs associated with conversion to urbanized uses. A successful PFA would thus be evident if it pulled development in from the surrounding rural lands, and resulted in a more rapid conversion rate. In a study of land use change in Maryland, (Irwin & Bockstael, 2002, see also Irwin *et al.*, 2006) found that PFAs significantly accelerated the rate at which rural parcels were developed, indicating that development was drawn in from nearby rural areas.

3.3 Other policies affecting rural land use

3.3.1 Critters, rural landowners, and the Endangered Species Act

Since so many species listed under the Endangered Species Act (ESA) rely upon private lands for their survival, and since the ESA prohibits harming listed species via detrimental alteration of their habitat, the ESA has a very tangible impact on land use and is highly controversial. Some have suggested that the impact of the ESA is to encourage landowners to either actively or passively discourage the presence of a listed species by management practices that change the species' habitat (Bean & Wilcove, 1997; Honnold *et al.*, 1997; Simmons & Simmons, 2003, among many others). The hypothesis forwarded is that, due to the ESA, landowners perceive an impending imposition of restrictions on their land use decision with potentially serious financial consequences, and as a result seek to avoid this constraint by eliminating habitat needed by listed species (or eliminating the species itself). This is the "scorched earth" technique where a property owner aims "to maintain the property in a condition such that protected species cannot occur on the property" (National Association of Home Builders, 1996).

Three recent studies, one from the western and two from the southeast U.S., provide some evidence as to the validity of this hypothesized relationship. Brook *et al.* (2003) surveyed landowners in Colorado and Wyoming to evaluate whether they had managed their land in such a way as to encourage or discourage the presence of a listed species, the Preble's meadow jumping mouse. 22% of landowners reported making land-management changes aimed at improving habitat for the mouse, while 14% altered their habitat to minimize the probability of the species' presence on their property. On an area basis, this amounted to a wash: as much acreage (25%) was managed to improve habitat as was managed to discourage the mouse's presence (26%). Furthermore, a majority of landowners, 56%, would not give permission for a biological survey to detect the presence of the species to be conducted. Interviewed landowners indicated that their reluctance was due to their perception of the risk that data collected could be used to regulate their property.

Lueck & Michael (2003) found "preemptive habitat destruction" by North Carolina landowners in response to the endangered red-cockaded woodpecker (RCW). Based on plot data from the U.S. Forest Service's Forest Inventory and Analysis data, they evaluated stand characteristics at varying distances from known RCW colonies. They found that stands closer to RCW colonies were more likely to be harvested, and were harvested at a younger age[19]. They conclude that the ESA has led to significant RCW habitat destruction as a result of landowner desire to avoid potentially costly land use restrictions. They estimated that between 5,090 and 15,144 acres of mature pine were preemptively harvested to avoid potential regulation and that in the Sandhills subregion, where RCWs are most abundant, approximately 5% of the subregion's suitable habitat was harvested[20].

Zhang & Flick (2001) also found that landowners in the Carolinas altered their land use decision in response to the presence of RCW habitat. They found that, after accounting for other influences, the possibility of reforestation is about 5% lower when the stand is close to known RCW habitat.

The deficiencies in the ESA have been recognized and adjustments have been made, e.g., the implementation of "Safe Harbor" agreements, which aim to provide landowners with greater regulatory certainty about the application of the ESA on their lands. While it is not clear how this will approach will develop over time, it is apparent that if Safe Harbor agreements do take hold widely, the Fish and Wildlife Service will have a hand in regulating a great deal of rural lands in the U.S., thereby influencing the land use decisions of a wide range of landowners (Simmons & Simmons, 2003).

3.3.2 Prescribed burns and landowner liability

Since many forested habitats in the South have historically developed in the presence of periodic fires, many forestland owners consider prescribed fire in their forest management activities. Nevertheless, a survey of fire managers in the South indicated that their willingness to use fire as a tool is constrained by a number of factors, including local public opinion, air quality and smoke regulations, and proximity to residential development (Haines *et al.*, 2001). The same study noted that risk of liability was a top consideration for national, state, and private forestland owners. An increase in the perceived level of liability risk would presumably lead to a decrease in the use of prescribed due to potential payouts for damage resulting from burning, and subsequent effects on forest cover in the absence of fire (see, for example, Platt *et al.*, 1991).

Sun (2006) reviewed the different types of tort liability legislation[21] affecting prescribed burns in all 50 states, and then explained the presence of different legislation types in the states based on a of series of factors related to forest land cover, population demographics, and state legislatures. He reports that all southern states – save Florida, Georgia, and Tennessee – assign simple negligence liability, an intermediate level of landowner liability, to landowners in

[19] The latter eliminates nesting habitat since RCWs typically nest in pines at least 70 years old.

[20] Given that a single RCW colony requires approximately 200 acres, the harvested acreage represents potential habitat for between 25 and 76 colonies – a substantial contribution considering the FWS recovery plan goal of 500 RCW colonies for North Carolina.

[21] "A tort is a civil wrong which is the result of some type of socially unreasonable and unacceptable behavior. In the case of prescribed fire, tort law provides the remedy to solve disputes between victims (i.e., plaintiff) and landowners (i.e., burner, injurer, or defendant)" (Sun, 2006, p. 3). The three types of tort liability legislation treated in Sun (2006) are *strict liability*, where landowners are liable for damages to plaintiffs even if their actions are entirely unintentional and nonnegligent; *simple negligence*, where landowners are liable only when plaintiffs prove carelessness or the lack of exercise of due care towards others or their property; and *gross negligence*, where plaintiffs must prove the lack of even slight care and the intentional failure of a defendant to carry out a duty towards others or their properties in a reckless disregard of the consequences of this activity. Detailed regulations specifying precautionary measures are typically passed along with prescribed burning tort legislation in order to clarify legal standards as to what consists of negligent behavior.

prescribed fire legislation. Florida and Georgia's legislation assigns the least liability burden on landowners, gross negligence, while Tennessee has no specific legislation regarding prescribed fire liability. The study explained the types of state legislation using an econometric model and found that the quantity of private forests, and especially industrial private forest, was the key factor in states' enactment of legislation lowering landowner liability. It did not however, evaluate the impact of the different liability levels on actual landowner behavior, and as such does not demonstrate that decreased liability translates into increased use of prescribed fire in forest management, and to quantifiable effects on land cover.

3.3.3 Forestry incentive programs

Forestry incentive programs can originate from federal or state governments, and the most common type of program are cost-share programs aimed at stimulating forestland owner investment by reducing landowners' initial reforestation costs and improving rates of return[22]. These efforts appear to be moderately successful at encouraging reforestation. Haines (1995) reported that federal incentives providing cost-share for tree planting on 467,000 acres nationwide. State programs contributed an additional 150,000 acres.

Mehmood & Zhang (2001) found that cost-share programs decreased the rate of parcelization. They identified two potential impacts of cost-share programs: first, that the programs may induce landowners to actively manage their forestland who had no intention of doing so previously, and second, that they increase the return to forestry investment. Zhang & Flick (2001) found that forestland owners receiving government cost-share payments spent less of their own capital, and that cost share programs had a favorable influence on reforestation rates.

Technical assistance programs, cost-share programs, and programs that provide forestland owners direct contact with foresters or natural resource professionals have been successful in the encouraging the application of sustainable forest practices on private holdings (Greene *et al.*, 2005). In a survey of state forestry personnel and forestland owners, they concluded that even successful programs aimed at encouraging sustainable forestry nevertheless played a minor role in forestland owners' land use and management decisions.

[22] USDA cost-share programs available to forestland owners include the Forestry Incentive Program (FIP), the Agricultural Conservation Program (ACP), the Stewardship Incentives Program (SIP), the Conservation Reserve Program (CRP), the Wetlands Reserve Program (WRP). State programs are too numerous to mention, and these tend to be less oriented towards timber production and more towards natural resource conservation.

4

SYNTHESIS

In the broad, population and income growth have been directly and indirectly driving many land use decisions in the South. The increase in absolute numbers of residents coupled with their increased purchasing power and preferences for rural lifestyles and large lots sets in motion a series of events that have broad impacts on land use and land cover.

Increasing demand for rural land has led to a boom in land values in developing areas. Development and increases in land values generate expectations of further development that may drive up land values even further. Great increases in land values influence land use decisions by making forestry use less competitive relative to alternate uses. In many areas the increase in land values leads to diminished investment in forestry, and can be so great that measures to counter conversion have limited chance of success.

A reasonably clear picture of the new nonindustrial private forestland owner emerges from the literature. Many are educated professionals seeking rural lifestyles, often first-time landowners, and often lacking in some knowledge of forest management. They have diverse preferences, many would harvest timber and probably all hold their land partly for nonmarket goods and services such as wildlife and recreation.

The changing face of forestland owners may have important implications. Many have speculated that land use will be significantly altered by this group of new landowners as a result of their perceived preferences for nonmarket goods and services derived from forests. However, new landowners do not appear to differ from longer-term landowners in terms of preferences as much as has been suggested. Furthermore, evidence indicates that longer-term landowners resembled the general population in many important ways. As a result, while the new crop of forestland owners' land use decisions will not be identical to the longer-term owners', it seems unlikely that dramatic shifts in land use will occur as a result of changing ownership.

Most analysis of forestland owner preferences has dealt with small- to medium-sized landowners. We know relatively little about very large landowners, those that own tracts of 1,000 acres and upwards. This is an important group despite the fact that they represent a very small fraction of all forestland owners. On the one hand, their holdings represent larger blocks of forest in an increasingly parcelized landscape, and second, they may have considerable financial resources to support their land use decision[23].

New forestland owners do appear to lack some knowledge of forest management, often report not knowing where to acquire information about management, and may not be well-informed when contracting services or making timber or land transactions. This has the potential to diminish the intensity of forest management, but the literature provides no indication as to whether this actually occurs.

Many have argued that the influx of residents with non-rural backgrounds will alter the general production environment in urbanizing areas, either via outright conflict or by the enactment of local regulations constraining forestry activity. While there appears little evidence that conflict has developed, increasing rural populations do appear to have generated greater local forestry regulations. Although this likely reduces returns to forestry use and thus reduces

[23] See for example, Condon & Putz (2006), who found Florida panhandle landowners investing in restoration on the scale of thousands of acres, a level far exceeding any state restoration effort encountered in the study.

its competitive position, no empirical studies in the literature have documented this effect in urbanizing areas.

Income, estate, and property taxes often play important roles in the land use decision. Estate taxes have been documented to result in both conversion of forestlands and unplanned timber harvests. The impacts of the other types of taxes are likely of similar importance.

Preferential property tax assessment programs have been widely implemented to counteract the influence of rising land values. Abundant evidence indicates that they amount to popular subsidies that have limited influence on land uses.

While the specific effects of growth management policies on individual landowner decisions are poorly documented in the literature, most authors agree that they do make a difference. Growth management policies may have important interactions that sometimes lead to less-than-predictable outcomes, and may be most effective when employed in concert for the same objectives. What is apparent is that growth management policies can have important economic impacts, such as on the cost of housing or the exclusion of certain socioeconomic groups.

If one thing is clear from the growth management literature, it is that how well any particular growth management technique works is often dependent on the institutional context within which it operates. That is, those efforts at growth management that have imposed similar constraints on communities throughout an entire region have shown much better success at achieving their goals than those implemented in highly localized fashion. The regional-scale failures of the latter initiatives have largely resulted from land market fragmentation that allows development to shift from locales where growth management regulations are strict to those more permissive of development.

It is not clear how the relationship between land use and the ESA will evolve. At present the act remains contentious, and studies have documented action on the part of some landowners to avoid the act's regulatory impact. The ESA affects a large land area and many landowners in the U.S., and so any changes to its implementation, such as the Safe Harbor program, have the potential to affect land cover on a considerable scale.

Programs aimed at encouraging forestry use throughout the country seem to be accepted by landowners on a significant scale. The common cost-share programs seem to be effective although some evidence suggests that their role in the land use decision is relatively minor.

Five land management outcomes relating to the ultimate driving factors of land use change in the South were identified in Figure 2. These contribute to the two land cover outcomes noted in the diagram: forest conversion to residential or other urban cover types, and the change in composition of remaining forest.

While estimates of the magnitude of forest conversion are present in the literature, the changing composition of remaining stands remains an open question. In particular, it is very difficult to draw from the literature the magnitude of shifts in the three management outcomes near the right of the diagram. It seems likely that the impermanence syndrome and changing ownership patterns will contribute significantly to diminished intensity of forest management, but it is not clear to what extent this might be true.

It is also not clear whether or how nonmarket management of forests will take hold. Large numbers of landowners interested in nonmarket benefits may encourage management activity, but their lack of management knowledge may make them reluctant to actively manage. In any case, it is apparent that a widespread "hands-off" approach to forest management – be it with the objective of market or nonmarket outputs – in the South will lead to large compositional changes to forests.

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Forest Service Southern Region
Changing Land Use Position Paper Project

Literature Review Part II: The consequences of land use change

By Brian Condon

1 Issues in characterizing landscape change in the South

1.1 Describing landscape change

While a number of transitions between different types of land use and land cover occur on a continual basis, our interest here is in the conversion of land from forest to other land uses, and the process can be examined at different scales. Wear (2002) estimated that 12 million forested acres would be converted to developed uses by 2020, with an additional 19 million acres converted between 2020 and 2040. Alig & Plantinga (2004) estimated a net loss of six million forested acres in the South by 2030. That their estimates differ significantly is less important to this discussion than what is not detected by these broad land use change models. Studies such as these that employ National Resource Inventory data in their analysis typically categorize land use as forested, agricultural, and urban. In these projections, the urban or developed category includes multiple components: urban and built-up areas (residential, industrial, commercial, and institutional land, railroad yards, etc.), small tracts of built-up land (10 acres and less), and land dedicated to transportation outside of built-up areas (see Natural Resources Conservation Service, 2006). As a result these studies are useful for describing broader-scale changes but they do not detect the nuances of development on the fringes of urban areas that are of particular significance to many of the goods and services we derive from landscapes.

The South's landscape, as elsewhere, does not consist of abrupt breaks between discrete types of land use. Understanding the role of urbanization in the loss of both natural habitat and working lands has been impeded by a lack of data that differentiate land use changes at and beyond the urban fringe (Theobald, 2001). Viewing the landscape as a continuum or gradient of development intensity is more useful in this discussion of the relationship between land use and ecosystem goods and services as many ecological processes do not change linearly or consistently with increasing levels of human influence (Theobald, 2004; Hansen *et al.*, 2005). One way to think of the landscape continuum is to consider the differences in processes and patterns as they vary from urban use to wilderness, as portrayed in Figure 1.1.

This is an important distinction since that portion of the continuum between high-intensity urban use and low-intensity rural uses is rapidly expanding throughout the U.S. Brown *et al.* (2005) found that in from 1950 to 2000, the area of low-density, exurban development[1]

[1] There are no standard definitions of urban, suburban, exurban, or rural land uses in the literature. Different authors and government agencies differ on both the number of divisions they consider between urban and wilderness or rural lands, as well as where the thresholds between divisions occur; see Theobald (2004). The definitions employed in Brown *et al.* (2005) were based on housing density: those areas with a density between 1 housing unit per 1 acre and 40 acres were considered exurban; higher densities were considered urban, lower densities rural.

beyond the urban fringe occupied nearly 15 times the area of higher density urban areas in the continental U.S. The exurban zone is where a number of changes discussed in Part I of the literature review manifest themselves. It is here where the parcelization process is occurring, and here where changing ownership may lead to changing management practices leading to changing forest composition.

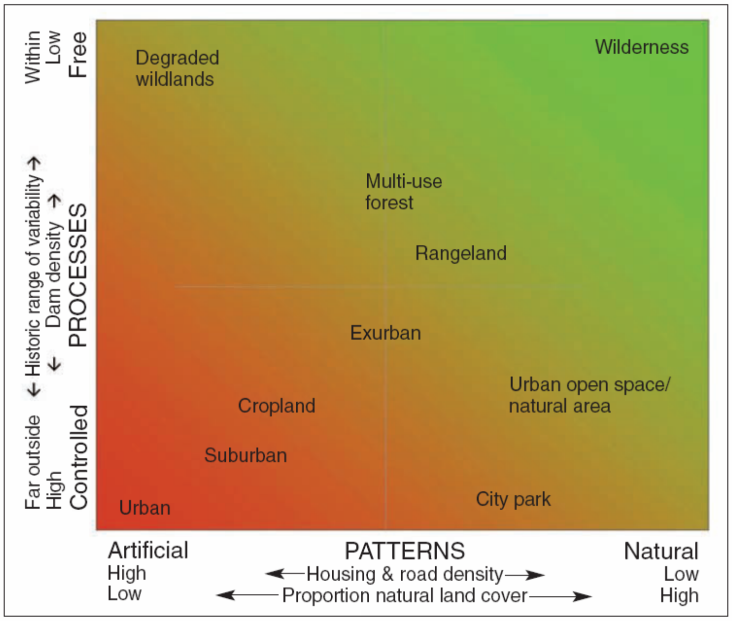

Figure 1.1: *The human-modified framework characterizes the degree to which natural processes are free or controlled, and landscape patterns are natural or artificial. Highly modified (e.g., urban) areas have artificial land-cover and -use patterns and tight control on natural processes such as wildfire and flooding. Lightly modified landscapes, such as wilderness areas, have natural patterns such as diverse composition and age structure, and natural processes such as wildfire are allowed to operate freely* (Theobald, 2004).

1.2 Structure and approach

The review that follows considers the effects resulting from the landscape changes described above, treating terrestrial ecosystems and aquatic ecosystems in turn. Clearly urban development has a great influence on the provision of ecosystem goods and services. Urban development fragments, isolates, and degrades natural habitats, simplifies and homogenizes species composition, disrupts hydrological systems, and modifies energy flow and nutrient cycling (Alberti, 2005). The consideration of land use change given here, however, is less oriented towards urban areas per se than towards the urban fringe, and pays relatively less attention to those studies largely or entirely focused on urban areas. The treatment of land use as a gradient of development intensity seems to be gaining steam in the landscape change literature, and every effort is made here to frame the discussion in terms of a gradient viewpoint.

2

LAND USE AND TERRESTRIAL ECOSYSTEMS

Urbanization and exurbanization in the South is eliminating some forest cover such that remnant parcels inhabit a matrix of developed uses. In addition to these habitat changes, urban land use itself alters such environmental attributes as temperature and precipitation. The sum of these changes has important consequences for both biodiversity, i.e., the number of species inhabiting a landscape, and species composition, i.e., the types of plants and animals inhabiting the landscape.

2.1 Landscape change in Southern forests

2.1.1 Fragmentation and habitat loss

In reviewing the literature for both Parts I and II, one gets a sense that we "know" a lot about habitat fragmentation. Both biologists and social scientists point to the undesirability of fragmentation, and how it might be mitigated. As discussed in Part I, many authors lament the process of forest parcelization, largely because of its attendant fragmentation. Like many phrases in technical fields however, "fragmentation" means different things to the different people who have created the voluminous literature on the topic, and a brief clarification of terms is helpful.

Fragmentation is important as habitat fragments tend to be biologically impoverished, often supporting widespread generalist species at the expense of specialists like interior forest species. Physical edge effects tend to be of great importance to forest fragments, where increased light and wind penetration, increased treefalls, and decreased humidity have been demonstrated to directly and indirectly affect much of the biotic community; these edge effects may render fragments of hundreds of acres as de facto edge habitats (Harrison & Bruna, 1999). Often however, it is not clear whether the impoverishment seen in fragments is due to smaller pieces of habitat or a lesser quantity of habitat across the landscape.

Many studies employ what amounts to a qualitative definition of fragmentation as a process where "a large expanse of habitat is transformed into a number of smaller patches of smaller total area, isolated from each other by a matrix of habitats unlike the original" (Wilcove *et al.*, 1986). This notion however, combines two concepts: habitat loss and fragmentation proper. A pane of glass contains no less glass if it is broken apart, although the pane is now divided into many pieces; only when some of the pieces are removed do we have less glass. When landscapes change due to human activity however, habitat loss and fragmentation almost universally occur simultaneously, as in Figure 1.2.1 (C).

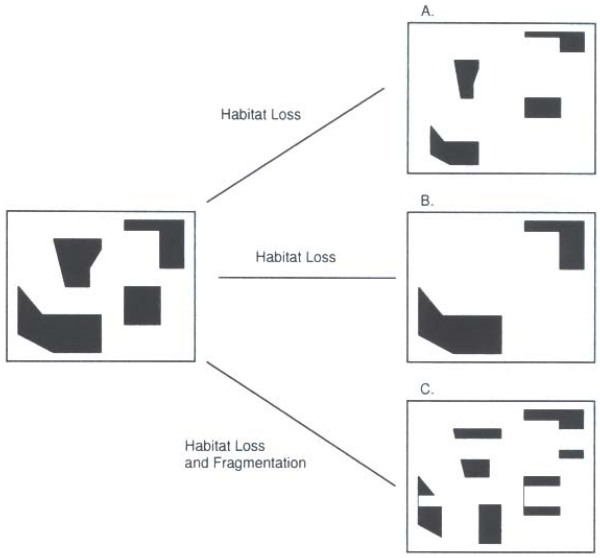

Figure 2.1.1: *Landscape change resulting in habitat loss, or habitat loss and fragmentation; black polygons indicate habitat* (Fahrig, 1999).

Confusion about the definition of the fragmentation phenomena often carries over to confusion about the effects of fragmentation on biodiversity, and most studies that purportedly evaluate the effects of fragmentation are largely confounded by the effect of habitat loss. One recent study found that while a search of the Cambridge Scientific Abstracts database yielded over 1,600 articles containing the phrase "habitat fragmentation," to the author's knowledge only 17 studies have been conducted that have quantitatively evaluated fragmentation per se (Fahrig, 2003). The overall result from those studies was that habitat loss has a much larger effect on biodiversity than fragmentation itself, and that when fragmentation did have an effect it was just as likely to be positive as negative.

Fahrig (2003) argues, "Habitat loss should be called habitat loss; it has important effects on biodiversity that are independent of any effects of habitat fragmentation per se. Habitat fragmentation should be reserved for changes in habitat configuration that result from the breaking apart of habitat, independent of habitat loss." The distinction may seem somewhat trivial, but it does have conservation significance in the sense that it takes away from the central result that the most important factor in species' declines is the decreased quantity of habitat, not the number of fragments into which it is broken.

2.1.2 Land cover change and human activity in the matrix of lost habitat

Forested habitat is converted into other cover types, and these types of land cover in turn affect remnant forest habitat. McKinney (2002) points out that habitat conversion associated with urbanization results in its replacement by four types of land cover, in order of increasing habitability to most native species:

1. Built habitat: buildings and impervious surfaces
2. Managed vegetation: residential, commercial, and other maintained green spaces

3. Ruderal vegetation: empty lots, abandoned farmland, and other cleared but unmanaged open space
4. Natural remnant vegetation: remnant patches of original vegetation

These land cover changes result in a number of physical changes to local environments that can have serious effects on biotic communities examined below.

Beyond land cover change, human activity within the habitat matrix alters natural disturbance regimes that influence the characteristics of terrestrial species populations, communities, and ecosystems. Episodic disturbances (events that disrupt ecological systems) shape the structure and function of ecosystems by changing the composition of communities, altering linkages in food webs, modifying fluxes of nutrients, and altering the basic physical structure of ecosystems (Dale *et al.*, 2000; Alberti & Marzluff, 2004). Important human-generated disturbances along the urban-rural gradient include those affecting soils, such as exposure of bare soil via vegetation removal, soil compaction, or burial of soil by fill material (Pickett *et al.*, 2001). Natural disturbance is also suppressed in settled areas, as in the case of fire suppression and flood control, both of which affect ecosystem structure and function. There are disturbances particular to habitat fragmentation along the rural-urban gradient: forest fragments may be more susceptible to natural disturbances such as windthrow, pest outbreaks, and invasion by exotic species (Dale *et al.*, 2000). Forest margins proximal to residential areas may retreat due to trampling associated with recreational use that can damage existing vegetation and eliminate regeneration (Pickett *et al.*, 2001).

Limiting resources are often subsidized in settled areas. Water and fertilizers applied to managed vegetation make these habitats very productive (McKinney, 2002). Cultivated plants in these habitats often bear fruits or seeds that are attractive to animals such as bats and birds, while some animals have adapted to the direct consumption of human resources provided intentionally or unintentionally (e.g., bird feeders and garbage bins, respectively) (Adams, 1994).

The road network is an important component of the matrix surrounding forest fragments that both physically alters the landscape and channels human activity. Trombulak & Frissell's review (2000) identifies a number of general effects. Road construction kills sessile and slow-moving organisms, and once completed, roads are a source of mortality from vehicle collisions, for some species the primary cause of death. The presence of roads may cause animals to shift their home ranges away from locales with high road density, alter their movement patterns, and alter their overall physiological state or their response to threats. Roads and their adjacent areas experience important physical transformations, such as soil compaction, increased heat storage, increased light penetration, and the generation of dust that settles on nearby plants. Maintenance and use of roads contribute heavy metals, salt, organic molecules, ozone, and nutrients to the local environment. Roads encourage dispersal of exotic species by providing altered habitat conditions, stressing or removing native species, or allowing easier movement of animal or human dispersal vectors. Finally, roads facilitate human use of formerly inaccessible areas, increasing pressure from consumptive and extractive activities.

2.2 Urbanization, exurbanization, and species richness

All the human activities noted above and a host of others not mentioned have an influence on both species richness and the types of plants and animals inhabiting the landscape.

2.2.1 The urban core

The effects of urbanization are felt in air and soil. Urbanized areas generally experience elevated temperature maxima and minima, and elevated temperatures can encourage ozone formation. Higher atmospheric particulates increase precipitation in and downwind of cities (Pickett *et al.*, 2001). Urban soils are susceptible to compaction, often have elevated contaminant levels, and can have dramatically altered nutrient cycling (McDonnell *et al.*, 1997). While not all species are susceptible to these types of physical changes, some species are sensitive to them, and as a result tend to drop out of urban communities.

The number of species of plants and animals tends to be lowest in core urban zones relative to more intact and undisturbed rural habitats. Species richness has been shown to be lowest in urban zones for diverse taxa. Much of this reduction in diversity is a result of the loss of the vegetation upon which higher tropic levels depend, and the area covered by vegetation tends to be a good predictor of species numbers for birds, mammals, amphibians, reptiles, and insects (McKinney, 2002). Nevertheless, urban forests are sometimes more species rich than rural stands, a somewhat counterintuitive result until one considers this additional diversity is due to the presence of exotic species (Zipperer *et al.*, 1997).

2.2.2 The exurban zone

Many plant and animal communities show diminished species richness with increasing development. Inasmuch as less native vegetation translates to less habitat in which to exist, this seems an intuitive result. The relationship between species richness and levels of development has often been found to be nonlinear, exhibiting thresholds beyond which richness of some taxa shows a precipitous decline (Figure 2.2.2; Hansen *et al.*, 2005).

Species richness in the exurban zone is often reported to be elevated relative to rural land uses nearby. Low to moderate levels of development are sometimes found to increase biological diversity in taxa including mammals, birds, insects, and plants (McKinney, 2002). The explanation often given for this is the “intermediate disturbance hypothesis” where the low percentage of the landscape altered during the initial stages of suburban sprawl is embedded in a matrix of largely natural or agricultural habitat. The resulting environmental heterogeneity is accompanied by additional species occupying the altered portion of the landscape, thus increasing the number of species. Studies have documented the phenomenon on diverse taxa, from ants to lizards to mammals (Nuhn & Wright, 1979; Germaine & Wakeling, 2001; and Racey & Euler, 1982, respectively).

Representative of such results is the study by Blair (1996) that found urbanization to affect birds in two ways: moderate levels of development can increased overall species diversity and decreased native bird diversity. Increasingly severe development, however, lowered both total and native species diversity. Moderate levels of development apparently increase diversity, but closer examination reveals that the increase in species richness results from the addition of widely distributed species at the expense of native species. This shift in the type of species is another important effect of habitat modification, and the subject of the next section.

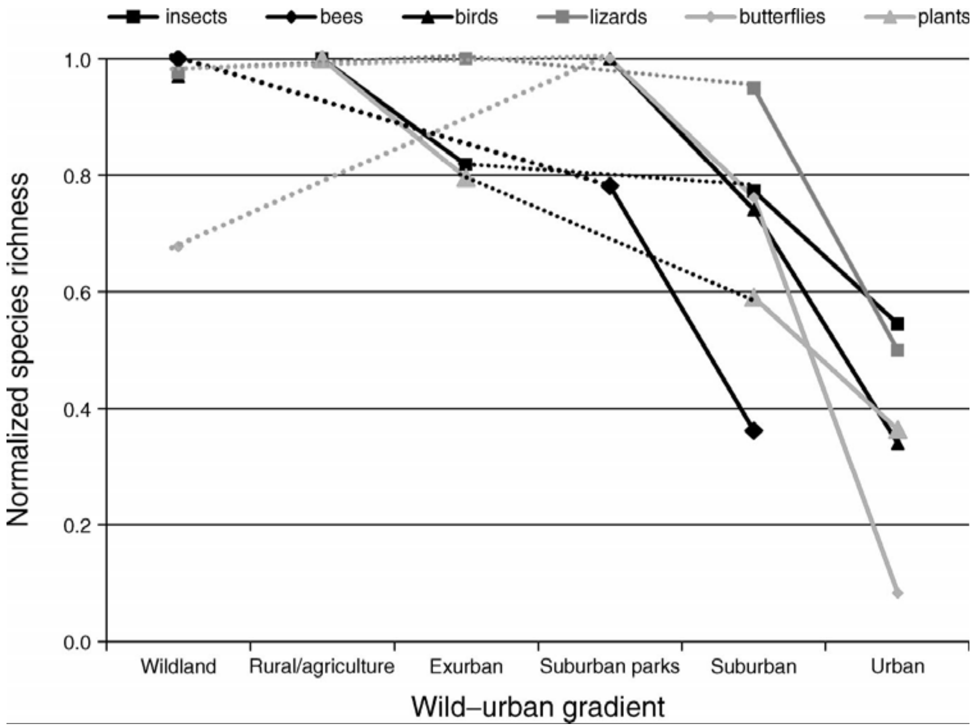

Figure 2.2.2: *Distribution of species richness across a gradient in land use for studies of various organisms. Normalized species richness is calculated as a function of the maximum number of recorded species at a point on the development gradient. Dashed lines represent unsampled portions of the gradient* (Hansen *et al.*, 2005).

2.3 Urbanization, exurbanization, and species composition

As human impacts have continued to spread across the landscape global species diversity has declined. Nevertheless, at local and regional scales species diversity has often increased because the rate of introduction of exotics has exceeded the loss of native species (Sax & Gaines, 2003). The local increase in the number of species occurs in hand with decreased landscape-level diversity, that is, increasing community similarity among regions. The compositional shift by which regionally distinct, native communities are gradually replaced by locally expanding, cosmopolitan, non-native communities is called biotic homogenization (McKinney & Lockwood, 1999).

2.3.1 Three categories of species in the rural-urban gradient

The general decline in the number of species is accompanied by a shift in the types of species occupying habitat remnants. McKinney (2002) observes that a number of bird and mammal studies have concluded that species along the gradient can be classified into three categories that reflect their response to human alteration of the landscape. The three types of species occur in fairly predictable locations along the rural-urban gradient, as depicted in Figure 2.3.1.

Urban avoiders are very sensitive to human impacts, and are largely absent in the most urbanized settings. Urban avoiders include large mammals, especially predators, as well as species adapted to the interior or large, old forests. Avian urban avoiders include tree-foraging insectivores, neotropical migrants, and ground-nesters that are very sensitive to the presence of humans and pets.

Urban adapters often include early successional plant species, commonly considered "weedy" species, such as wind-dispersed lawn weeds and bird dispersed invasive shrubs. Faunal communities tend to include many "edge" species. Adapters often benefit from food sources associated with settlement, such as garbage or cultivated plants, and often have low predation pressure due to the elimination of their main natural predators, and as a result can become much more abundant than in natural settings.

Urban exploiters are those species that are largely or entirely dependent on human settlement for survival. Exploiters include plants that tolerate high levels of disturbance, air pollution, trampling, and compacted, nitrogenous, and alkaline soils. The combination of predator removal and abundant food subsidies can lead to avian and mammalian urban exploiters to achieve immense populations. Avian exploiters tend to be ground-foraging seedeaters or omnivores, while mammalian exploiters are typically omnivores able to find shelter in human dwellings.

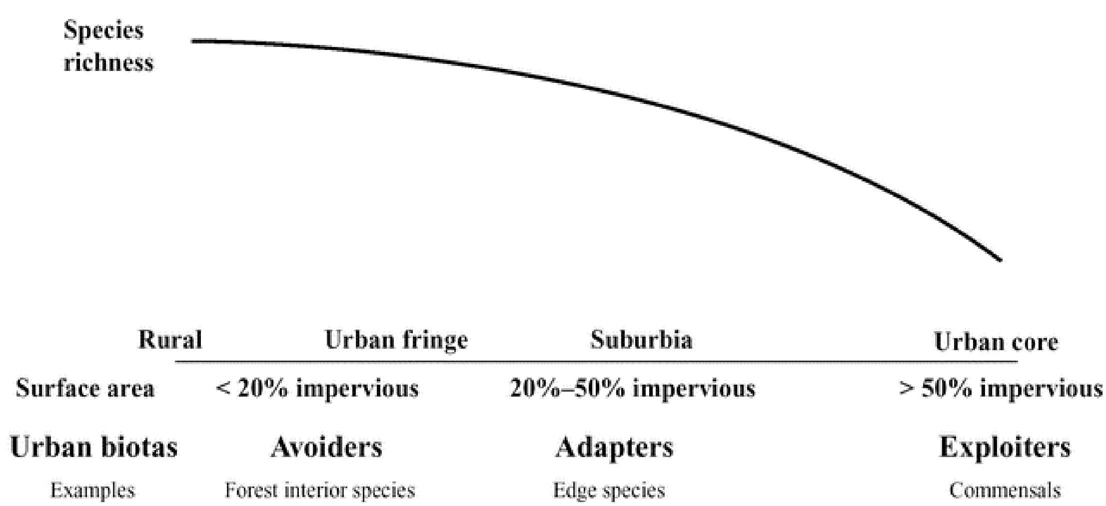

Figure 2.3.1: *Generalized depiction of biodiversity and species composition across the rural-urban gradient* (McKinney, 2002).

2.3.2 The influence of nonnative species

While native plant and animal species richness generally declines with increasing urbanization, the opposite is often true for nonnative species (Hansen *et al.*, 2005). Many studies have found that the number and proportion of nonnative species tends to increase towards core urban areas along the urban-rural gradient. The increased presence of exotics in urban areas can be attributed to the greater number of people, who are generally quite adept at introducing any number of nonnative plants or animals. High levels of disturbance in urbanized areas can also promote the proliferation of exotic plants and animals (McKinney, 2002).

Nonnative species in urban and exurban environments can be an important driver of diminishing species richness and shifting species composition. Fragmented habitats provide opportunity for the incursion of aggressive competitors or predators with deleterious effects on the native fauna is a common occurrence and may exacerbate the physical edge effects of fragmentation. Penetration often involves exotic species or aggressive natives that attain high abundances near edges because they are subsidized by resources in the matrix (Harrison & Bruna, 1999).

Riparian forests often exist as linear fragments in the urban-to-rural gradient, and two studies from Georgia indicate that invasions of the sort described above may lead to important structural changes in the long-term. Burton *et al.* (2005) found that non-native species dominance of riparian woody plant assemblages in western Georgia increased with increasing proximity to urban centers. The understory dominance of exotic *Ligustrum sinense* (Chinese privet) seemed to suppress regeneration of overstory native riparian-zone trees. Loewenstein & Loewenstein (2005) also found that overstory regeneration potential was substantially impacted in the presence of *Ligustrum* and *Microstegium vimenium* (Nepalese browntop). The implication is that as these riparian forests age and senesce, canopy recruitment may not occur, and the stand may degrade into a shrub thicket or meadow, thus diminishing the ecological values of the riparian forest. It further implies an additional potential cost to riparian zone management, exotic species control.

2.4 Land use change and consumptive forest goods and services

Thus far we have only considered the nonconsumptive benefits of forests. That is, people do not directly consume species richness, although it may be a significant consideration to their enjoyment when recreating in and around forests. Clearly the fiber produced by forestlands in the South is also consumed by people as well.

2.4.1 Timber supply

Fiber supply from the South's forests is a function of supply from both industrial and nonindustrial forest owners. As discussed at length in Part I of this review, the two ownership types hold different preferences, and as a result respond differently to different economic signals. While industrial owners can be assumed to be interested in timber production and respond largely to financial incentives, nonindustrial forest owners as a group hold forestland for multiple objectives, such as recreation or wildlife habitat, in addition to timber production. Nearly 4.7 million nonindustrial forestland owners hold approximately 60% of the South's forestlands (Birch, 1997). It is unclear exactly how the changing ownership of forestlands in the South will affect their management and thus the timber they supply, but since industrial forestlands contribute proportionately more supply to the fiber market, it seems unlikely that changing land use in the South will greatly affect supply overall.

Prestemon & Abt (2002) project that while the total area of private timberland will decrease by 1% in the South, pine plantation area is expected to increase by 60%. This expansion in plantation acreage coupled with productivity gains due to improved management is projected to increase industrial wood output in the South by more than 50% by 2040 relative to its 1995 level.

2.4.2 Recreational use

The ability to recreate on private land is essentially a question of access by outsiders. Little information is available in the literature regarding private land recreation, the only study encountered was the National Private Landowner Survey, whose results are reported in Teasley *et al.* (1999). The survey reports that one-third of rural landowners do not allow access to their land to anyone outside their family. Only 15 percent of respondents indicated that they allowed people whom they did not know on their land, and the tendency seems to be towards more restricted access in the future. Furthermore, much recreation on private land takes place on corporate lands that are leased to groups for seasons or entire years, while individual landowners tend to afford little access to outsiders. The survey reports that most landowners allow access to their lands in order to maintain goodwill with their neighbors, in addition to modest amounts of income that leases can provide. While the former motivation might be expected to remain steady in the future, changing forestland ownership to more affluent individuals, as is the trend, may result in owners placing less emphasis on the latter, and as a result granting less access in the future. The fragmentation of ownership may reinforce this trend, although it is difficult to support such an assertion in the absence of empirical evidence.

3

LAND USE AND AQUATIC ECOSYSTEMS

Hynes's pithy observation that "In every respect, the valley rules the stream" gets to the core of the relationship between land use and aquatic ecosystems (Hynes, 1975, cited in Allan, 2004). Land use affects the physical and chemical characteristics of surface waters, which in turn influence habitats and biotic communities in important ways (Naiman & Turner, 2000).

Human use of the land correlates highly with water quality indicators, and water quality outcomes due to land use change can be predicted with a fair level of certainty. For example, Bryce *et al.* (1999) developed a "relative risk index" for watersheds in the mid-Appalachians. Based on land use information gleaned from topographic maps, aerial photographs, and field visits, the index assesses the probability of the watersheds' impairment. The relatively coarse resolution information of their low-cost method was sufficient to generate an index consistent with measures of stream conditions based on water chemistry and benthic macroinvertebrates on a regional scale.

Much research on the topic has been conducted in two veins: comparisons of characteristics of forested v. agricultural v. urban basins; and evaluations of the impacts of specific practices, such as road construction or riparian zone management[2]. Swank & Crossley (1988) note that the joint consideration of the quantity, timing, and quality of streamflow provides an integrated measure of the impact of management activities on aquatic ecosystems. This section follows that approach and then considers the biotic impact of these changes.

3.1 Land use and the quantity and timing of streamflow

Precipitation either runs off the landscape or infiltrates into the soil, where it may be taken up by plants and transpired or pass through and contribute to subsurface water[3]. Land use influences potential evapotranspiration by altering surface vegetation, and alters the relationship between infiltration and runoff by compacting soils or capping them with impervious surfaces. While the southeastern U.S. receives abundant rainfall, less than half of the annual precipitation falling on forested lands contributes to streamflow in the region due to its hot climate and high evapotranspiration (Sun *et al.*, 2005b).

3.1.1 Stream hydrology

Forest cover generally yields relatively lower surface flows as forests encourage infiltration and transpire much fallen precipitation. Different forest types have differing influences on hydrologic regimes. Water yields are highest in the South's mountainous regions that receive the highest precipitation and have the lowest air temperature, while coastal regions dominated by wetlands receiving moderate rainfall but high evapotranspiration have the lowest water yields (Sun *et al.*, 2005b). Removal of forest cover in upland hardwood watersheds would

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[2] The literature relating land use to impacts on surface waters goes back many years and is expansive; the review here is far from comprehensive. Readers are referred to two particularly helpful recent works: Allan (2004) provides a concise treatment of land use impacts on surface waters, while Paul & Meyer (2001) provide an authoritative discussion of the ecology of urban streams.

[3] Swanson *et al.* (2000) provide an accessible overview of the hydrologic cycle and its relationship to land cover.

likely increase streamflow to a greater degree than conversion of lowland forests in watersheds with shallow water tables, where tree removal may have an insignificant impact on total runoff and thus limited downstream impact (Sun *et al.*, 2002). Swank *et al.* (2001) found that streamflow increased 28% following clearcutting in a southern Appalachian watershed.

The increase in impervious surface cover (ISC) associated with urbanization has a number of effects on hydrology. ISC speeds the arrival of stormwater to surface basins, resulting in more rapid flooding. Floods are also of shorter duration and more frequent, and peak discharges are higher in urban catchments (Hirsch *et al.*, 1990; Allan *et al.*, 1997). ISC also impairs infiltration, and heavily urbanized areas may experience runoff levels five times greater than forested areas (Table 3.1.1; Arnold & Gibbons, 1996). Less rainfall thus infiltrates, diminishing groundwater recharge and reducing baseflow levels in urban streams (Barringer *et al.*, 1994; Wang *et al.*, 2001).

Table 3.1.1: *Effect of impervious surfaces on hydrologic flows* (Arnold & Gibbons, 1996).

	Land cover			
Hydrologic flow	Forested	10-20% Impervious	35-50% Impervious	75-100% Impervious
Evapotranspiration	40†	38	35	30
Deep infiltration	25	21	15	5
Shallow infiltration	25	21	20	10
Runoff	10	20	30	55

† Percent of flow

3.1.2 Stream geomorphology

In addition to increased volumes of stormwater discharge, urbanization can contribute significant sediment loads to streams, in particular during construction of developed areas. Paul & Meyer (2001) describe the changes to stream channels in two phases: the aggradation phase and the erosional phase. The aggradation phase results from increased sediment delivery to streams due to soils exposed by urban construction. Sediment yields can increase two to four orders of magnitude over areas under forest cover, and this sediment is deposited in the streambed and its banks. Once urbanized, sediment contributions diminish but runoff increases due to increased ISC. These increased flows lead to increased channel erosion, and channels get progressively deeper and wider. The process results in the loss of pool habitat and instream cover, in addition to excessive streambed scouring and deposition (Wang *et al.*, 2001).

In the past, the presence of large pieces of woody debris in waterways was viewed as a liability and as a result this debris was often removed. Removal of riparian vegetation results in a loss of woody debris in the streambed and on stream banks. Coarse woody debris such as logs can dissipate stream energy and alter the geomorphology of streams (Marston, 1982). Coarse woody debris supplied by riparian forests and temporarily stored in the bed or on river banks is no longer considered a factor contributing to increased flood risk and impact. In some streams it has been shown that logjams provide important fish habitat due to the creation of sheltering structures (Piégay & Landon, 1997).

3.2 Land use and water quality

Alterations of the landscape due to urbanization and exurbanization of watersheds has a pronounced affect on sediments and aquatic chemistry in surface waters.

3.2.1 Sediments

The exposure of soil during construction is important since individual erosional events can have long-lasting impacts on surface water ecosystems. In an experimental watershed in the southern Appalachians, large increases in sediment loads occurred following two storm events immediately after logging road construction, although during and after logging the sediment loads diminished. The cumulative increases in sediment loads were observed downstream for 15 years, illustrating the extended lag between isolated depositional events and the subsequent movement of those sediments through the stream system (Swank *et al.*, 2001). Similar impacts have been found by a number of other researchers (e.g., Hagans *et al.*, 1986). Nevertheless, even after establishment, even paved roads can route fine sediments to streams, lakes, and wetlands (Trombulak & Frissell, 2000).

In a study of three catchments with differing land use – forested vs. agricultural vs. urban – in the North Carolina Piedmont, Lenat & Crawford (1994) found that agricultural and urban runoff increased suspended sediment concentrations and sediment yields relative to the forested basin. Sediment concentrations during storm events were similar for all three, while the agricultural site yielded the highest load during low-moderate flows.

3.2.2 Nutrients

Urbanization typically results in nutrient enrichment of surface waters (Paul & Meyer, 2001; Jones *et al.*, 2001; Schoonover *et al.*, 2005). While nitrogen levels in agricultural watersheds often exceed either forested or urban watersheds, urban streams can show levels comparable to agricultural streams (Lenat & Crawford, 1994; Nagumo & Hatano, 2000). Both particle-associated and dissolved phosphorous may be elevated in urban streams (Paul & Meyer, 2001; U.S.Geological Survey, 1999). Elevated levels of both nitrogen and phosphorous in urban watersheds can be attributed to wastewater discharge, septic tanks, and inorganic fertilizer use (Mainstone & Parr, 2002; U.S.Geological Survey, 1999).

3.2.3 Contaminants

Urban streams often contain elevated levels of metals in both the water column and sediment. Point sources such as industrial sites contribute metals to urban streams, but runoff from impervious surfaces is an important source as well since higher concentrations of metals can be found near stormwater outflows (Rhoads & Cahill, 1999). Pesticide concentrations in urban streams can exceed those observed in agricultural areas, a major source are those applied around households, industrial sites, and golf courses (U.S.Geological Survey, 1999). Pesticides principally reach urban streams via runoff (Foster *et al.*, 2000). A number of other organic contaminants ranging from polychlorinated biphenyls, to petroleum-based hydrocarbons and even pharmaceutical compounds are also routinely found in urban streams (Paul & Meyer, 2001). Runoff from paved areas can contain deicing salts, and result in periodic surges in aquatic salt concentrations (Mattson & Godfrey, 1994). Beyond urban areas' contributions of sediment loads and contaminants to surface waters, underground storage tanks that may leak petroleum products to groundwater are typically encountered in urban areas, as are abandoned wells that may facilitate groundwater contamination and land fills that may contribute a variety of contaminants (Zipperer *et al.*, 2000).

3.2.4 Temperature

Removal of riparian vegetation, decreased groundwater recharge, and the heat island effect associated with urban areas all affect stream temperature. Streams may be cooler in winter and warmer in summer, and seasonal diurnal fluctuations can also be greater in urban areas due to the influence of summer storm runoff from ISC (LeBlanc *et al.*, 1997; Paul & Meyer, 2001).

3.3 Biotic impacts of land use change

The sum of physical and chemical impacts described above that are generated by land use practices in turn influence habitats and biotic communities in complex ways (Naiman & Turner, 2000). Biotic impacts of urbanization are relatively understudied, and studies of impacts on invertebrate populations are more common than those evaluating fish, while particularly neglected are studies of population and community dynamics (Paul & Meyer, 2001).

Microbial densities tend to be elevated in urban streams, largely attributable to combined sewer overflows during storm events (Young & Thackston, 1999). Schoonover *et al.* (2005) found elevated fecal coliform level in urbanized watersheds, often exceeding U.S. EPA standards for recreational waters.

As with terrestrial communities, roads have important impacts on aquatic ecosystems. The effects on aquatic ecosystems of deicing salts originating from paved areas are largely unstudied. One study did indicate that salt elevated chloride and sodium concentrations altered plant succession in an Indiana bog (Wilcox, 1986). Roads can act as physical barriers to the movement of fishes in streambeds, potentially cutting them off from habitats important to certain life stages (Rieman *et al.*, 1997).

Helms *et al.* (2005) compared urban, agricultural, forested, and “developing” (i.e., suburban) watersheds in the western Georgia Piedmont, and found that developing watersheds more closely resembled urban than forested watersheds in terms of fish assemblages. They found that progressively greater percentages of urban land use in stream basins was associated with consistently greater signs of deteriorating health in fish assemblages. They also found that declining proportion of fish in environmentally sensitive breeding guilds and decreasing measures of fish biotic integrity was associated with increasing watershed urbanization.

Similar results were found by Walters *et al.* (2003) in northern Georgia’s Etowah River basin, an areas of high fish diversity and endemism. This study found that urbanization converted clear, coarse-bedded streams into turbid streams with finer beds. These conditions favor cosmopolitan species over endemic taxa, and fish assemblages were found to be homogenized in urban areas.

Schleiger (2000) also found that nonpoint and point source runoff from low-density urban areas negatively influenced the number of fish species in Georgia streams. Higher levels of suspended solids associated with urbanization generally had a negative influence on the number of sensitive species and overall numbers of fish. Fish assemblages were composed of proportionally more tolerant species, and greater proportions demonstrated diminished health, evidenced by eroded fins, lesions, or tumors.

A wide range of fish species in a variety of stream types are sensitive to suspended sediments (Newcombe & Jensen, 1996). Ill effects of suspended sediments may be lethal or nonlethal and reduce productivity, survival, or growth of fishes; some species and life stages show “ultrasensitivity” to suspended sediment.

Lenat & Crawford (1994) found that forested and agricultural streams had similar fish species composition, although the abundance and size of some species was greater in the agricultural site. Their urban site demonstrated low species richness, an absence of intolerant species, and low biomass. Invertebrate taxa richness, a biotic index, and the number of unique invertebrate species indicated that their agricultural site was moderately stressed with moderate water quality relative to their high-water-quality forested site. The same criteria evaluated at the urban site indicated a severely stressed stream with poor water quality.

3.4 Quantity and configuration of development's impact on aquatic ecosystems

There appears to be some indication that once urbanization occupies a certain proportion of land cover, it has a profound negative influence on the aquatic environment. The spatial arrangement of developed and forested land uses within watersheds is not well understood, but evidence suggests that it is also significant to surface water health.

3.4.1 Thresholds of urbanization

Land development that removes forest cover and undisturbed soil can result in higher-volume storm flows that lead to accelerated channel erosion and habitat simplification. Booth *et al.* (2002) evaluated the relationship between forest cover, impervious surface area, and stormwater impacts in King County, WA. They hold that the magnitude of forest-cover loss is at least as important as associated increases in impervious area in typical rural land use situations. They further argue that land development in the study area has exceeded the level where structural controls such as detention ponds can mitigate the increased storm flow resulting from conversion of forest to urban use.

Their result seems consistent with Wang *et al.* (2002), who found that once connected impervious areas exceeded a threshold of 8-12% of a watershed, that the influence of urbanization on stream quality was so dominant that it overshadowed other land use influences on stream fish communities or base flow.

3.4.2 Spatial configuration of development

While much research has established the link between land use and water quality impacts, little has been done to evaluate the spatial distribution of land use on water quality. Wear *et al.* (1998) argue that two locations along the rural-urban gradient hold disproportionate influence over water quality: the most remote portions of the landscape, and the outer envelope of urban expansion.

Morley & Karr (2002) found that the effects of urbanization on physical stream conditions are influenced by both spatial scale and landscape patterns. Their results indicated that urbanization of both the entire contributing watershed and the portion of the watershed closest to the stream appear to have approximately equal weight in influencing stream physical conditions. The study also found a similar relationship with respect to biological contions.

McBride & Booth (2005) note that urbanization in watersheds is highly influential to streams and likely sets a maximum attainable best condition, but that conditions are strongly modified by the local landscape conditions. Importantly, they found that physical conditions can improve downstream from degraded stream reaches if the riparian zone is substantially forested and contains few road crossings.

3.5 Land use change and water supply

While land use does influence the quantity and timing of streamflow, other factors appear to be at least as important. Topography has an important influence on watershed baseflow patterns and stormflow peak and volume (Sun *et al.*, 2002). Sun *et al.* (2005a) considered both natural and socioeconomic factors to estimate water supply and demand in the southern U.S. over the next 25 years. Their model results indicated that climate change was expected to have the largest influence on water supply, while population growth and land use change have progressively lesser impacts. Overall, they estimate that increased water stress induced by climate change and population growth will exceed the water stress relief resulting from land use conversion from forest to urban uses, although the effects will not be uniform throughout.

4

MAINTAINING THE FLOW OF ECOSYSTEM GOODS AND SERVICES FROM THE LANDSCAPE

4.1 Terrestrial ecosystems

4.1.1 Overcoming fragmentation with connectivity

A number of theories have been forwarded about how fragmentation affects biodiversity[4]. These theories have emphasized the spatial aspects of fragmentation and the role of dispersal among habitat remnants and habitat configuration and connectivity (Harrison & Bruna, 1999). This has led to conservation prescriptions involving spatial strategies such as dispersal corridors that will be discussed further on. However elegant are the theories, empirical results are often inconclusive.

One common strategy for maintaining populations of plants and animals in fragmented landscapes has been to maintain habitat corridors between fragments. These corridors are thought to increase the exchange of individuals between habitat patches, promoting genetic exchange and reducing population fluctuations. In their review of the corridor literature, Beier & Noss (1998) conclude that generalizations about the value of corridors are difficult to make because their value is species specific. They did find that of the dozen well-designed studies in the literature, 10 offered persuasive evidence that corridors provide sufficient connectivity to improve the viability of populations in connected habitats, and that none demonstrated negative impacts from corridors.

Since the Beier & Noss review, a group of researchers have studied corridor use by a variety of taxa in an experimental South Carolina landscape (Damschen *et al.*, 2006; Tewksbury *et al.*, 2002; Levey *et al.*, 2005; Haddad *et al.*, 2003, among a series of additional publications). Their studies evaluated the response of species of butterflies, small mammals, birds, and plants to corridors created within extensive pine plantations. Overall, they found that the corridors in their experimental landscape consistently directed the movement of the various taxa, including the first evidence that corridors affect the interpatch movement of plants via impacts on pollination and seed dispersal.

While the South Carolina researchers consider their studies "large-scale," their study area consisted of experimental plots located within a research area approximating a circle less than 30 km in diameter, and as such are far from regional in scale. Nevertheless, their studies were substantially bigger than "the only study to demonstrate experimentally that corridors can enhance population persistence" cited by Harrison & Bruna (1999): a study of invertebrate fauna inhabiting fragmented patches of moss on rocks.

An important issue in evaluating the impact of corridors is whether they are effective for local populations, or whether they can have regional influence. Harrison & Bruna (1999) argue that few large-scale studies showed either direct or indirect evidence for the importance of

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[4] These include island biogeography (MacArthur & Wilson, 1967), metapopulation dynamics (Hanski, 1998), and source-sink models (Pulliam, 1988).

movement among habitat fragments, and as a result there is little proof of the efficacy of corridors at promoting regional species persistence.

In summary, the influence of corridors in maintaining populations of plants and animals in fragmented habitats is not entirely known. It appears that they are effective locally for a fairly wide range of fauna, although their impact on plants is little studied. Furthermore, the question of whether they have regional value, even if they are effective locally, remains to be answered.

4.1.1 Other terrestrial measures

Evidence suggests that the maintenance of forested cover in urban environments may be of little value as wildlife habitat for many species. For example, Stratford & Robinson (2005) found that large scale habitat attributes influenced local species richness of migrant birds more than smaller scales in Georgia. They concluded that small woodlots in urban settings had little conservation value for migratory birds, and that preservation of large areas of green space in urbanizing landscapes should be given higher priority.

4.2 The aquatic environment

4.2.1. Best management practices

As Allan (2004) notes, "reversal of land use to a less-developed state at the catchment scale is rarely practical, and so improvement of stream condition more often depends on best management practices (BMPs) and improvements in landscape management and design" (p. 275). BMPs may be implemented in uplands adjacent to watersheds, or near to watercourses themselves. Examples of the former include conservation tillage of agricultural fields, barnyard runoff controls, reduction of fertilizer use, or a change in the types of fertilizers applied; riparian BMPs include fencing to exclude livestock, stormwater retention ponds, managed wetlands, rip-rapping, or the establishment and maintenance of designated vegetated riparian zones.

Most studies evaluating the physical, chemical, and biotic impacts of BMPs have either evaluated either riparian zones exclusively, or riparian zones in combination with other upland or riparian BMPs. As a result, the evidence as to the efficacy of some upland and riparian BMPs is scarce, or is difficult to separate from the important effects generated by riparian zones. The applicability of available information is also limited somewhat by the fact that most studies of BMPs have been conducted in agricultural landscapes. Despite the lack of concrete data specifically relating individual BMPs to hydrologic impacts, it seems clear that they do have favorable impacts, as with the reduction of soil and nutrient loss due to conservation tillage (Gaynor & Findlay, 1995).

A representative result of watershed-scale impacts of upland agricultural BMPs along with riparian BMPs is provided by Wang *et al.* (2002). They found that riparian BMPs improved habitat quality in localized areas, and yielded wider benefit when implemented in concert with upland BMPs. Although the study evaluated BMPs affecting cold-water Wisconsin streams in an agricultural environment, it does indicate that reasonable alterations in land use on the level of individual landowners can yield positive results for aquatic environments.

Nerbonne & Vondracek (2001) found that riparian management showed greater effectiveness in improving stream chemistry and sediment loads than did upland BMPs. They cautioned however, that the design of their study may have masked the effects of upland management, and noted that trout had returned to their former range in the study site after improvements in upland management practices. This they considered as an indication of the importance of maintaining upland BMPs.

In a study of 47 small Wisconsin watersheds with land use ranging from predominantly agricultural to predominantly urban, Wang *et al.* (2002) found that the area of connected impervious surface[5] in a watershed was the best proxy for measuring urbanization's effect on the physical and biotic characteristics of streams. Their results suggest that minimizing connected impervious area and maintaining buffers in and near riparian zones would significantly reduce the impacts of more conventional patterns of urban development.

4.2.2 Riparian zones: the interface of the valley and the stream

Riparian zones are important to mitigating the adverse impacts of land use for two reasons: first because their immediate and direct influences on stream conditions are well-documented, and second, because they provide benefits that are highly disproportionate to their land area (Allan, 2004). Riparian zone management has been effective in ameliorating many ecological issues related to land use and environmental quality, including the restoration of aquatic systems (Naiman & Decamps, 1997).

By preventing outputs from agricultural lands from reaching stream channels, riparian forest ecosystems are excellent nutrient sinks that buffer the nutrient discharge from surrounding agricultural ecosystems (Lowrance *et al.*, 1984). Nevertheless, riparian zones cannot compensate for all hydrologic ills resulting from land use change, as when the mitigation capacity of riparian buffers is overwhelmed when a large proportion of watersheds change from forested to urban land uses (Allan, 2004).

Naiman & Decamps (1997) note that in addition to their ecological functions, riparian forests are increasingly expected to contribute to social functions such as the provision of recreational opportunities and aesthetics. This suggests that the opportunity costs of land dedicated to riparian areas may not be minor relative to the consumptive benefits of nonmarket goods and services that they afford. The preferences of forestland owners discussed in Part I provide some support to this view.

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[5] Connected impervious surface refers to those impervious surfaces (e.g., parking lots, sidewalks, roofs, etc.) having direct connections to downstream drainage via surface drainage ways or storm sewers.

5

SYNTHESIS

Clearly, land use change is of great importance to biodiversity, and may be the most important factor in terrestrial biodiversity conservation (Sala *et al.*, 2000). The rise of exurban development in the U.S. is of great importance to society's derivation of ecosystem goods and services. In 2000 the area of exurban development in the U.S. was nearly 15 times that occupied by urban areas, and further expansion of this land use will come at the expense of agricultural or forested uses.

Exurbanization results in both habitat fragmentation and habitat loss. While the effects of the former appear to be limited in terms of biodiversity, the latter clearly has had led to both local and regional declines. Activities associated with people in the matrix surrounding remnants, such as disturbance, resource subsidization, and road networks, all have important detrimental impacts on the composition and structure remnant forest parcels within the exurban landscape.

As one progresses along the gradient from rural to urban land uses, species richness shows a general decline for many plants and animals, although the relationship is often nonlinear. That is, some studies have shown increases in richness in exurban areas, and others have documented a gradual decline in richness, followed by a sharp decline once a threshold of developed land use is reached.

The types of species also vary along the urban-rural gradient. As one advances towards core urban areas, certain species, the so-called urban avoiders, drop out of assemblages while others, such as urban adapters and nonnatives, become more common.

Further complicating the picture is the temporal aspect of biodiversity change. Hansen *et al.* (2005) note that changes to species richness and species composition may take decades to fully manifest themselves following exurban development. As a result, biodiversity is likely still responding to the earlier waves of exurban expansion that began following WWII.

It remains an open question however, the degree to which biodiversity per se contributes to some goods and service flows from the landscape, such as the average resident's enjoyment of the landscape. That is, it is not clear whether the South's residents derive the greater utility from viewing, visiting, or living near a species-rich native pine savanna as from a slash pine plantation, or for that matter a stand of invasive Melaleuca. If residents are indifferent to such alternative cover types, or if they are unable to detect subtler differences in diversity, it seems unlikely that they would respond strongly to efforts to maintain or enhance biodiversity per se on their properties or immediate surroundings.

It appears unlikely that land use change in the South will decrease the supply of fiber in the region. Conversion of forests to exurban uses and multiple use management of nonindustrial forestlands are expected to be more than countered by the expansion of plantations and increases in productivity.

The supply of recreation on private land however, may decrease due to increasingly fragmented ownership and the changing demographic characteristics of forestland owners. Nevertheless much recreation on private lands occurs on industrial parcels under contractual agreements with user groups, and it seems likely that the availability of these recreational opportunities will remain fairly steady.

Land use is critically important to the health of aquatic ecosystems. Increasing levels of urbanization have detrimental effects on the quantity and timing of streamflow that in turn alters stream geomorphology. Urbanization also degrades water quality, generally increasing sediment loads, nutrient content, and contaminants. These physical and chemical effects combine to degrade biotic communities in heavily urbanized areas. The spatial configuration of land use is also important, as less intensive land uses proximal to watercourses tend to aid in maintaining aquatic ecosystem health.

While the issue of water supply and demand in the South has not been extensively studied, some evidence suggests that water stress induced by climate change and population growth will exceed water stress relief resulting from changing land use from forests to urbanization.

Preservation of small forest fragments in heavily urbanized areas does not likely contribute significantly to the maintenance of biodiversity. Limited evidence suggests that maintaining habitat corridors connecting habitat fragments can contribute to maintaining biodiversity.

Detrimental effects of intermediate levels of urbanization can be partially mitigated by the implementation of best management practices such as stormwater retention facilities or the reduction in fertilizer use within watersheds. The maintenance of riparian forests should be broadly encouraged due to the highly disproportionate benefits that they provide relative to the small area they occupy.

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